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Original Communications

THE PROBLEM OF THE HIATUS HERNIA OF THE DIAPHRAGM

Conrad R. Lam, M.D., and Leo J. Kenney, M.D. (by invitation)
Detroit, Mich.

THE problem of the hiatus hernia of the diaphragm is actually twofold. One aspect is represented by the dilemma of the internist who must advise the patient in whom this hernia has been demonstrated. This patient may be told to "forget it" or to change his habits of eating and sleeping and to take palliative drugs in an attempt to make the situation tolerable, or he may be advised to consult a surgeon about an operation. The other part of the problem is that faced by the surgeon, who in the face of conflicting advice must choose and carry out an operative procedure. So great has been the confusion with regard to technical details and so far from ideal have been the results from the methods actually selected that the perplexity of the internist is understandable. Obviously what is needed is a standard curative operation which can be used by any thoracic surgeon on practically any patient with hiatus hernia of the diaphragm. It is our belief that such an operation is currently available and that it should be employed to the exclusion of all others.

Naturally the logical plan of operative treatment of hiatus hernia would include reduction of the herniated structures back into the abdominal cavity and closure of the aperture to maintain this reduction. There have been reports of large series of cases repaired by the transabdominal[1] and transthoracic[2, 3] routes. Although these authors have indicated that in their hands these procedures have not been associated with an important recurrence rate, others[4, 5] have reported a discouraging number of failures. In fact, several authors have advised that attempts at definitive repair are not worth while and that it is preferable to enlarge rather than diminish the hernia orifice, so that the stomach is not constricted.[6, 7] A similar attitude of defeatism is represented by those who recommend interruption of the phrenic nerve.[8]

From the Department of Surgery of the Henry Ford Hospital.

Read at the Thirty-third Annual Meeting of The American Association for Thoracic Surgery, San Francisco, Calif., March 27, 28, and 30, 1953.

In an early series of eighteen patients with repair of hiatus hernia by the transthoracic approach by one of us (C. R. L.), there was a discouraging number of recurrences. At least six had roentgen evidence of recurrence of which four had return of symptoms and two had second operations. An example of rather prompt recurrence is shown in the roentgenograms in Figs. 1 and 2. This

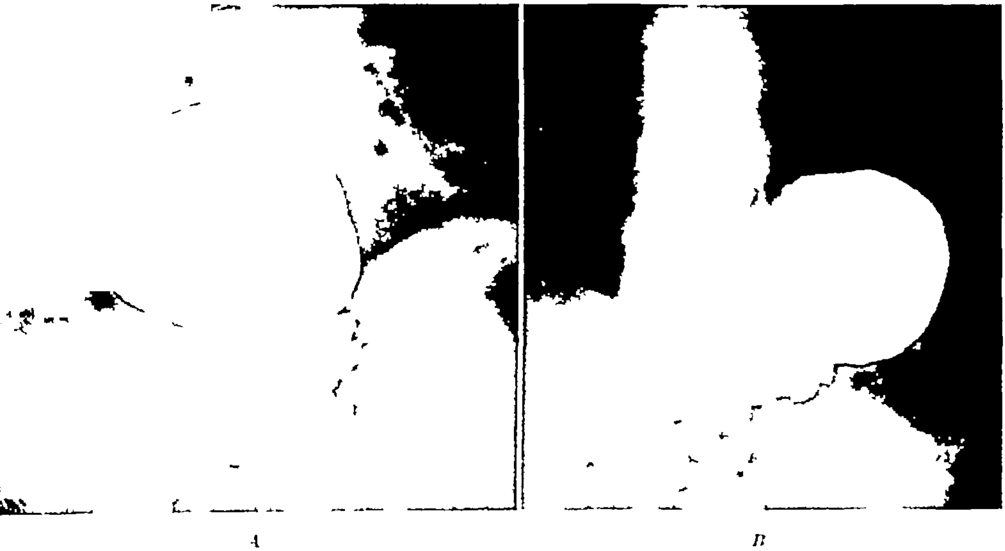

Fig. 1.—*A*, Preoperative roentgenogram of large hiatal hernia. The central location in the mediastinum is striking. *B*, Postoperative roentgenogram taken five weeks after repair by unsatisfactory technique. The beginning of recurrence is evident.

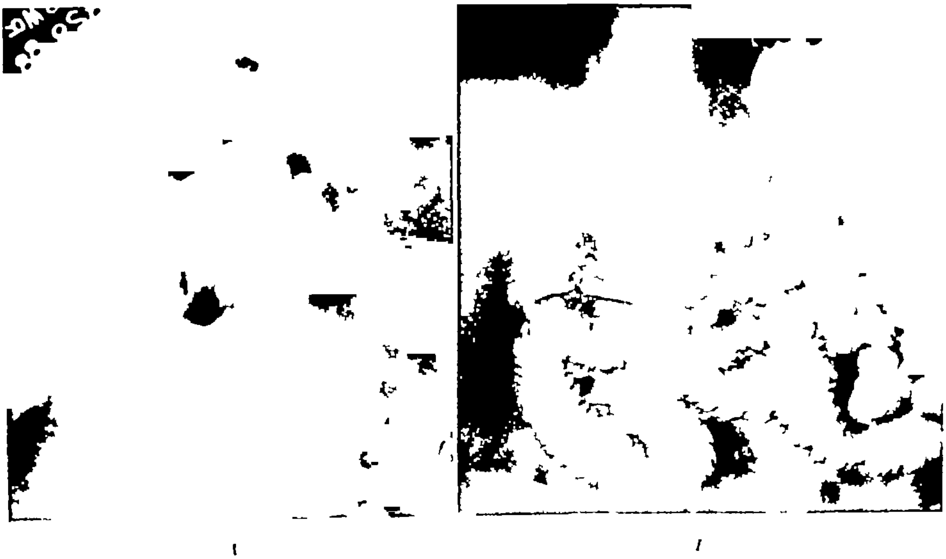

Fig. 2.—*A*, Roentgenogram of patient shown in Fig. 1 four years later showing large recurrence with upside-down stomach. *B*, Roentgenogram after second repair of hiatal hernia by recommended method (eight months postoperative).

experience led us to the logical conclusion that there was some fundamental defect in the method of repair which was being utilized The technique employed in this unfortunate series might be summarized as follows 1 The hernia was exposed through an incision through the left eighth interspace and an attempt was made to obliterate the peritoneal sac by excision and/or plication

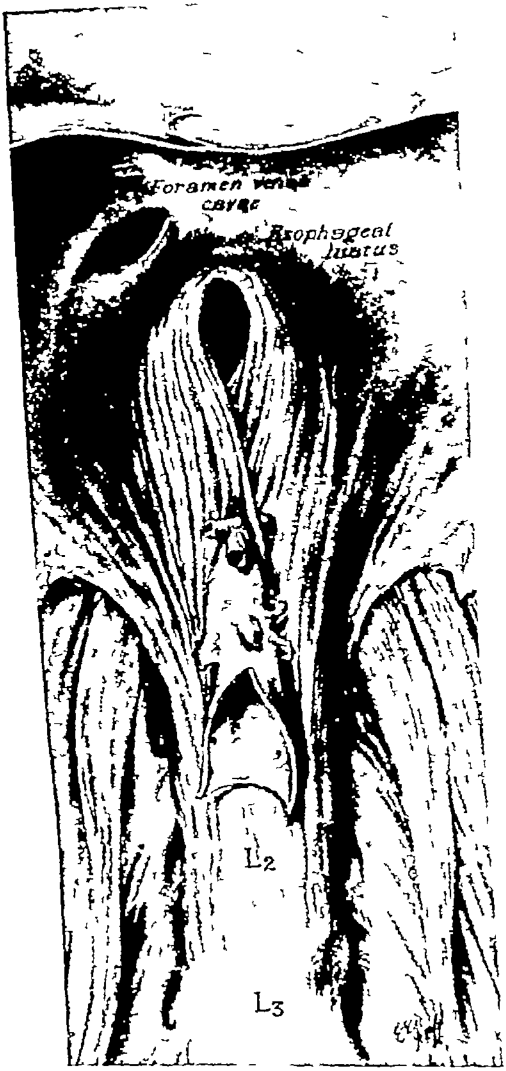

Fig 3 —Artist's drawing of inferior surface of diaphragm Herniation through the esophageal hiatus occurs after lengthening and widening of the posteroinferior part of the aperture

2 The size of the hernial orifice was reduced by the placing of sutures in the most accessible location which was usually at the anterolateral portion of the circumference of the hiatus At least two authors[1] [2] had described the esophageal hiatus as being frequently a transverse slit, which could be closed by placing sutures to the right, to the left, or on both sides of the esophagus

It is our opinion that the true long axis of the esophageal hiatus lies in the sagittal plane and that an anteroposterior suture line behind the esophagus is the most effective. Merendino, Varco and Wangensteen,[9] Allison[10] of Leeds, and Effler and Ballinger[11] came to the same conclusion. Each of these three excellent papers contains directions for an anatomically sound repair of uncomplicated hiatus hernia by the approximation of the crura behind the esophagus. However, in two of them[9, 11] attention was probably diverted from this important matter by the emphasis which was given in the titles and the bodies of the papers to the problem of the so called short esophagus and the necessity of incising the diaphragm out toward the dome for the transplantation of the esophagus laterally and anteriorly.

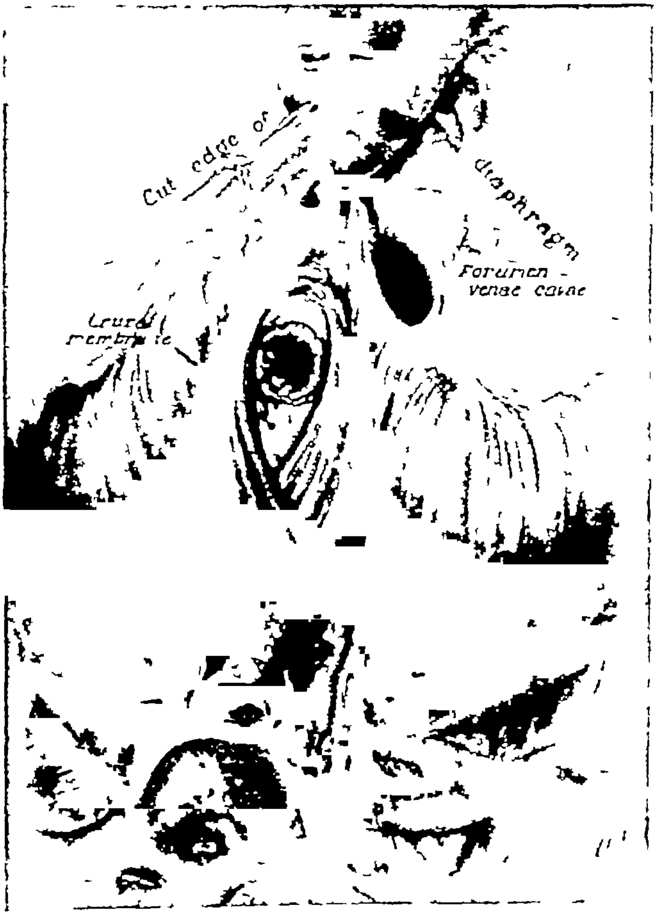

Fig. 1.—Artist's drawing of superior surface of the diaphragm. Herniation occurs through the area occupied by the crural membrane.

To supplement the anatomic information obtained during operation on patients with hiatus hernia, we made dissections of the diaphragms in eight cadavers and drawings were made.*

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*By Mr. Elton Hoff, medical artist.

The crura of the diaphragm take origin from tendinous attachments that arise from the anterolateral surfaces of the bodies of the first three lumbar vertebrae The fibers become muscular and surround the aorta at the level of the celiac axis These muscular bundles pass upward in an interlocking manner soon separating to form the esophageal hiatus They then insert into the middle leaf of the central tendon

The inferior surface of the diaphragm is illustrated in Fig 3 The right crus is made up of muscle that originated from both the right and left sides of the vertebral bodies and a similar situation exists in the formation of the left crus The medial and lateral margins of the esophageal hiatus consist of those fibers that took origin contralaterally On the thoracic surface (Fig 4) the crura exhibit the same decussating phenomena

The anterior margin of the esophageal hiatus consists of unyielding tendinous tissue of the middle leaflet of the central tendon The posterior aspect of the hiatus is notably free of any firm structure In every dissected specimen the area posterior to the esophagus consisted of a triangular space that was bridged by a thin areolar membrane This is designated as the crural membrane in Fig 4 It is at this site that the abdominal contents find their way into the mediastinum creating a hiatus hernia We are convinced that obliteration of this anatomically weak area is of primary importance in the repair of this hernia

In addition to the anatomic studies we carried out some physiologic studies on the effect of phrenic nerve stimulation on the musculature of the diaphragm When the fingers were placed in the enlarged hiatus of a patient with hernia and the phrenic nerve was stimulated mechanically or by faradic current, there was retraction of the dome of the diaphragm but no tendency to contraction of the crura forming the rim of the hernial orifice In the experimental animal (dog), stimulation of the phrenic nerve did not cause the left crus to contract (Fig 5) Measurements of the pressure in a hydrostatic bag placed in the esophageal hiatus showed only slight increase in pressure when the phrenic nerve was stimulated (Fig 6)

Relaxation of the hiatus after section of the phrenic nerve could not be demonstrated These observations suggest that concomitant paralysis of the left phrenic nerve is of no value in the procedure of hiatal herniorrhaphy, and that it may actually do harm since postoperative pulmonary complications may be induced by the depression of respiratory function. It has been difficult logically to explain the palliation which has been reported in some patients who have had phrenic nerve interruption for hiatus hernia, although it has been assumed that the "spasm" of the hiatus is relieved[8] Amendola[12] recently has made an observation which may explain some of the instances of symptomatic benefit after phrenic paralysis Permanent phrenic interruption had been carried out on an elderly woman, with the result that the diaphragm rose high on the left chest, pulling the fundus of the stomach with it and thus reducing the hernia However, the esophagus became so angulated where it passed around the muscular ring that dysphagia appeared, and it was necessary to operate and transplant the esophagus anteriorly and laterally to the dome of the diaphragm.

The procedure which we recommend for the repair of hiatus hernias of the diaphragm is as follows. The lower left thoracic cavity is entered through a posterolateral incision through the seventh interspace. The pleura overlying the esophagus (pulmonary ligament) is divided to permit a tape to be passed around the esophagus (Fig. 7). The pleural covering of the herniated stomach and retroperitoneal fat is brushed off to expose the muscular edge of the hiatus.

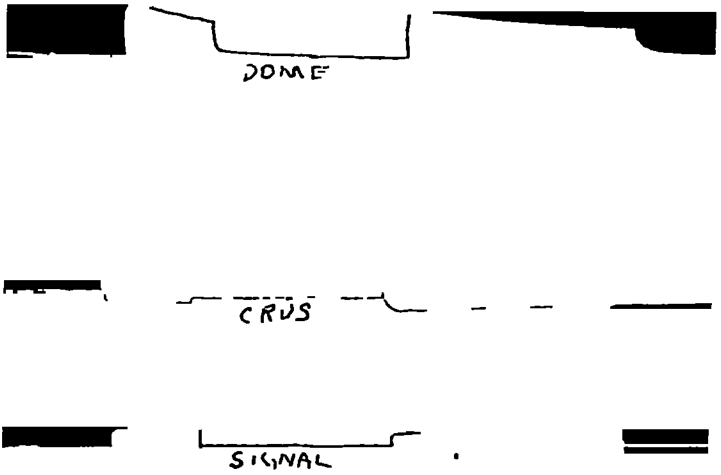


Fig. 5.—Kymograph record showing motion of dome of diaphragm and lack of motion of left crus during stimulation of left phrenic nerve. The writing points were activated by strings passing superiorly from the two parts of the diaphragm.

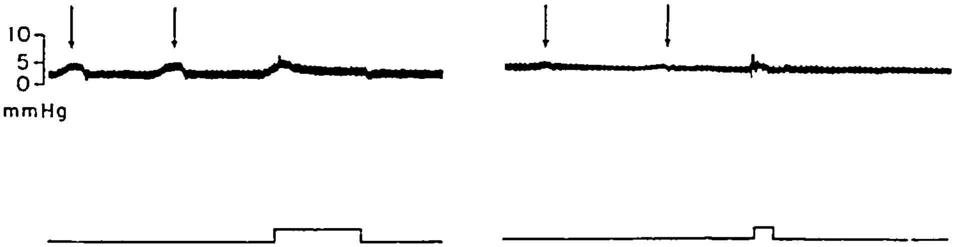


Fig. 6.—Pressure recordings from a hydrostatic bag placed in the esophageal hiatus of the dog (Hathaway apparatus). The record on the left shows the slight pressure fluctuations of normal inspiratory movements (arrows). Sustained faradic stimulation of the left phrenic nerve (lower signal) caused no greater fluctuation. The record on the right shows that no relaxation was produced by section of the phrenic nerve (signal).

A small incision is made in the dome of the diaphragm and a long clamp is passed intraperitoneally along the under surface of the diaphragm to pierce the peritoneum near the anterior surface of the hiatus and emerge from the hiatus. This clamp grasps the tape which encircles the esophagus and draws it out of the opening in the diaphragm. During the subsequent repair traction on this tape assists greatly in maintaining reduction and providing exposure for the suturing of the crura (Fig. 8). The esophagus is easily displaced anteriorly after the division of a small amount of areolar tissue and a vessel or two.

Fat and areolar tissue are cleaned off the right crus so that sutures can be placed accurately. However it is the palpating finger which actually guides the placement of these sutures. It will be found that the medial portion of the

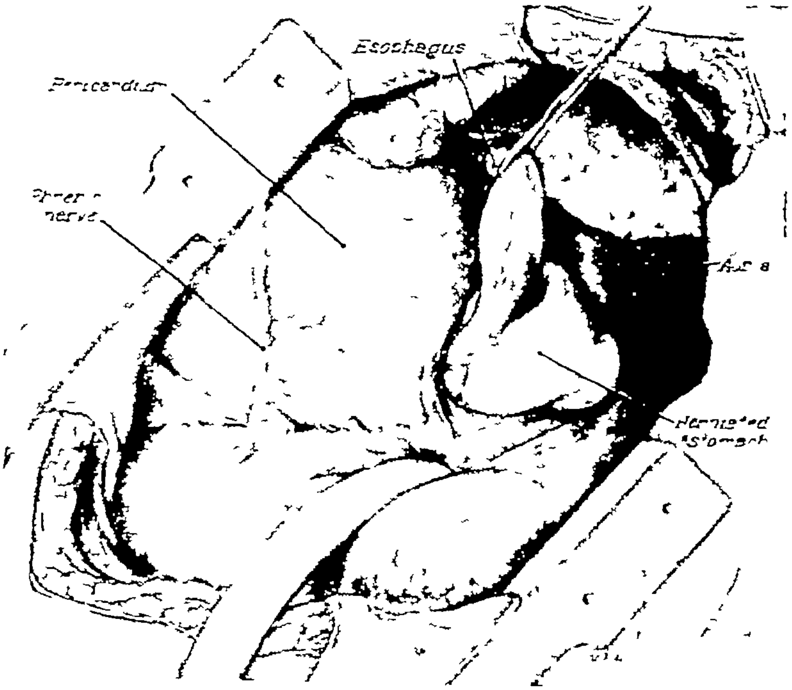


Fig 7.—Exposure of hiatal hernia through left posterolateral seventh interspace incision.

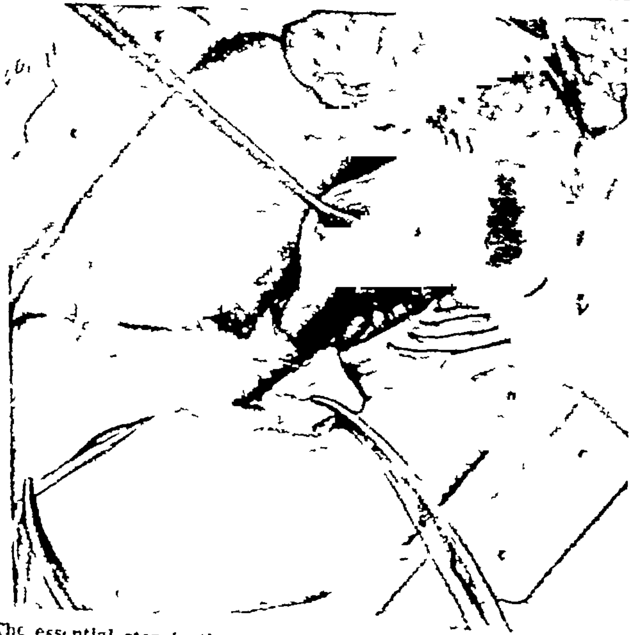


Fig 8.—The essential step in the repair of hiatus hernia, the placing of sutures through the crura posterior to the esophagus. Note the tape passed around the lower end of esophagus and through a small opening in the dome of the diaphragm which helps to maintain reduction.

orifice (commonly called the right crus) is fibrous and tough and holds sutures well while the lateral portion (left crus) is composed mainly of muscle and there is a tendency for sutures to tear out. To obviate this, the sutures should pass through all layers of the diaphragm, including the diaphragmatic pleura.

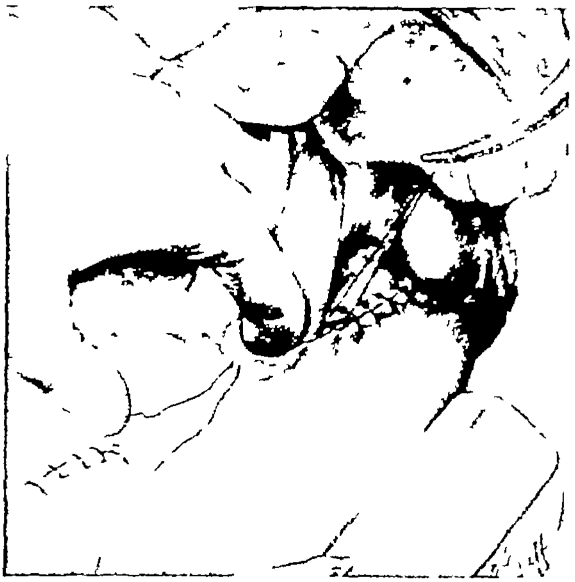
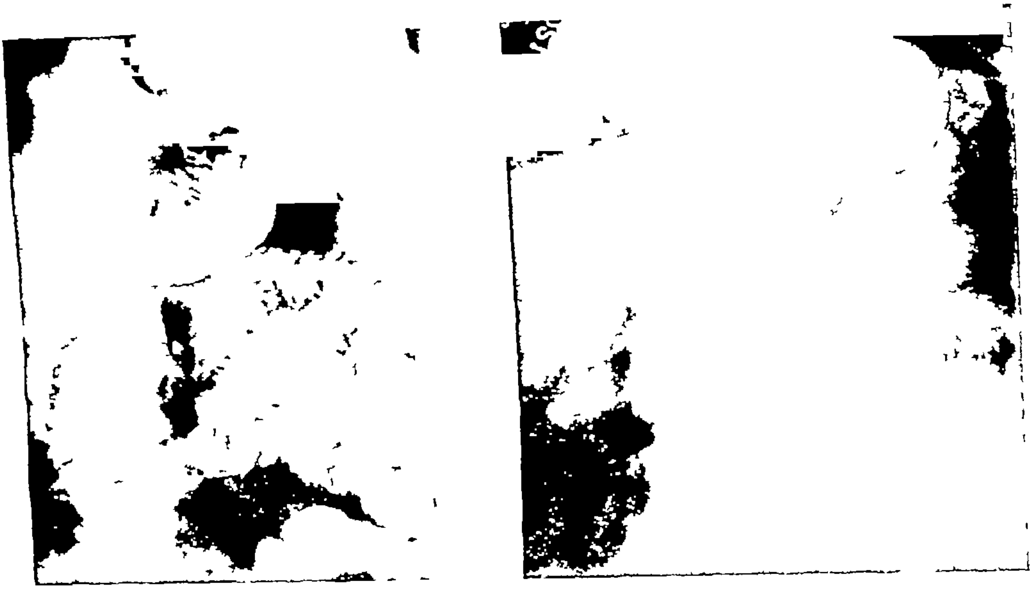


Fig. 9.—Final closure of esophageal hiatus with finger inserted to prevent too tight closure. The small incision in the dome of the diaphragm has been closed.

Usually five or six sutures placed posterior to the esophagus are all that are necessary. Before these sutures are tied, three or more mattress type sutures are placed which attach the esophageal musculature to the under surface of the esophageal hiatus. These sutures correspond to those which Allison recommends for the fixation of the so-called phrenoesophageal ligament to the under surface of the diaphragm. The posterior sutures are then tied; a finger is inserted in the orifice by the side of the esophagus as the most anterior one is tied (Fig. 9). No dysphagia has been produced when this precaution has been observed in determining the size of the opening.

It will be noted that no attempt was made to excise or plicate the peritoneal sac if one existed. It is our opinion that since this lesion is a sliding hernia no useful purpose is served in removing a small amount of peritoneum on one side of the sac.

Since the above technique was adopted, twenty hernias have been repaired. In preparation for this report all patients were recalled, questioned for symptoms of recurrence and submitted to roentgen examination. The follow-up period on nine cases was from one to two years and in six others was from six months to one year. In no instance has there been roentgen evidence of recurrence (Fig. 10). Seventeen patients are asymptomatic. Two of the others had persistence of dysphagia from pre existing esophagitis and are improved following dilatation Another patient with recurrence of gastrointestinal symptoms has recently undergone cholecystectomy for cholelithiasis



A

B

Fig 10 —A Preoperative roentgenogram of hiatal hernia of moderate size B, Postoperative roentgenogram following repair by recommended method (seven months after operation)

There has been no mortality in the thirty-eight patients with transthoracic repair of hiatus hernia Aside from the recurrences in the early group, there has been no morbidity of note with the exception of one patient who developed a large hemothorax which became infected after a number of thoracenteses Drainage by rib resection was necessary

We have not observed a case of so called "short esophagus" which would have necessitated a deviation from the technique described

SUMMARY

The unsatisfactory general status of surgical treatment of esophageal hiatus hernia of the diaphragm has been described This appears to be due to lack of standardization of the definitive operation An anatomically sound repair with closure of the opening by sutures placed posterior to the esophagus as recommended by previous authors appears to give the best promise of success

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DISCUSSION

DR. ALEXANDER L. WADA, New York.—I enjoyed the careful review and critical appraisal of the various surgical procedures for the treatment of hiatus hernia, as presented by Drs. Lam and Kenney. The multiplicity of operations and the high percentage of failures attest to the confusion that prevails today in the treatment of this lesion. It explains in some part the reticence of our medical confreres in recommending surgical therapy. Past experience, coupled with an honest scrutiny of our results, indicates that uniform success attends the procedure recommended by Allison and the anterior transplantation of the esophagus suggested by Wangensteen. The following case illustrates the result obtained by these combined techniques.

This patient was 65 years of age and came to me in 1949 because of a massive gastric hemorrhage.

(Slide.) This is a lateral x-ray view of the chest showing the entire stomach with the exception of the pylorus to be within the thorax and (slide) the barium enema shows that part of the transverse colon was present in the hernia sac.

An Allison repair with anterior transplantation of the esophagus produced a satisfactory end result. A small oblique incision of sufficient size to admit the assistant's hand was required in the left upper abdomen in order to maintain the stomach within the abdomen during the repair of the diaphragm.

(Slide.) This film was taken some time after operation following a barium swallow. You can readily see the left leaf of the diaphragm with the cardia of the stomach in its normal position and also see that there is no recurrence of the hernia.

We have observed esophagitis in varying stages as an associated disease. The etiology of this lesion remains controversial. We have resected the esophagus and performed an esophagogastrostomy in four such cases with one death.

(Slide.) This x-ray film after the ingestion of barium depicts the advanced stage of the disease which we interpret as hypertrophic esophagitis with stenosis.

Our last patient operated on two months ago for this lesion had previously undergone an Allison repair for a recurrent hiatus hernia in 1950. We thought that the esophagitis that existed at that time was reversible as it did not appear to involve the entire wall of the esophagus. Despite the cure of the hernia the esophagitis progressed, an ulcer perforated into the mediastinum with mediastinitis and there were two episodes of massive hemorrhage. This case was successfully completed by performing a Lewis operation in one stage. Through a midline abdominal incision the stomach was mobilized maintaining circulation from the right gastric and right gastroepiploic arteries. The patient was then turned on the left side and the right thorax was opened through the sixth rib bed. The lower half of the esophagus was resected and an intrathoracic esophagogastrostomy was completed. To date the result has been satisfactory.

DR E K JOHNSON, New York—I think that the problem of herniation through the
ophageal hiatus has been very clearly presented by Drs Lam and Kenney I rise only
cause we have seen this condition in the newborn infant, and until then I was unaware of
e possibility The first case was that of a newborn infant with obstructive symptoms of
gurgitation and vomiting The diagnostic procedure for atresia of the esophagus of pass
g a small catheter into the esophagus was employed Radiopaque oil was instilled into
e catheter and the fluoroscopist reported a small pocket above the diaphragm The symp
oms of obstruction abated and no surgery was performed In the next case similar
mptoms had occurred and the diagnostic procedure was repeated About ten hours later
e infant started swallowing normally The roentgenogram revealed a hiatus hernia In
e third case with similar symptoms the diagnostic procedure demonstrated a hiatus hernia

(Slide) At your left is the lateral roentgenogram showing radiopaque material in the
sophagus and in the herniated portion of the stomach To the right is an anteroposterior
oentgenogram showing air filled viscus in the mediastinum back of the heart shadow

The hernia was repaired by a transabdominal approach as I was uncertain of the diagnosis The elastic pleural esophageal membrane described by Dr Kenney had herniated on the right side and the left lobe of the liver projected upward into that space A small loop of bowel was al o present but I do not believe it was there normally The repair was similar to that Dr Kenney has described by displacing the esophagus in an anterolateral direction and bringing the two crura of the diaphragm together The repair seemed secure

We have a complete record of our case since at the end of one month of life the infant was found dead evidently from suffocation by crib blankets An autopsy showed that the *diaphragm* was normal the repair had held securely and there was no apparent shortening of the esophagus

We believe these patients might be of some interest because it was thought they had atresia of the esophagus The diagnosis was clearly established by the catheter radiopaque oil method I do not know why the first two infants were relieved of symptoms and the third continued to be obstructed unless as has been stated an associated esophagitis may be the cause

DR RICHARD H SWEET Boston—I was impressed by Dr Kenney s beautiful drawings of the anatomic situation which he found, but they rather surprised me because I have almost never found such a situation at operation as demonstrated there In all the patients, some 150 or more that I now have had experience with there is always a sac in the first place This sac is always anterior I have never seen a peritoneal sac posterior and I do not see how anatomically it could exist there There is however often a bulge of the stomach posteriorly without a true sac behind The sac is always in front, embracing the portion of the stomach that has slid up through the hiatus but not completely It never surrounds it as it appears to do in Allison s drawings for example Although I agree completely with him in the principles he has elaborated, his drawings are misleading because they allow one to believe that the hernia sac completely encircles the stomach which it does not do and which it cannot do

I certainly agree with Dr Lam and Dr Kenney that the posterior approximation of the margins of the diaphragm at the hiatus is the important thing but I find also that the direction and the configuration of the hiatus are exceedingly variable Sometimes it is exactly L shaped with a smooth rounded border Sometimes it is elliptical and although one feels that the posterior sutures are the more important, occasionally I find it necessary to use a few sutures in the front mostly to the right in this elliptical type of aperture This is of importance I believe, because in one of the patients I had with recurrence, although the integrity of the hiatus remained there was a recurrence up under the pericardium in this little triangular defect which is sometimes seen These are always sliding hernias

One other point which I think is worthy of comment, which Dr Harrington might have brought up if he were here, is that if one is fearful of the sutures tearing loose, which I doubt very much if heavy suture material is used, it is a great help to use strips of fascia taken from the patient's left thigh

DR EARLE B KAY, Cleveland —I have employed a somewhat similar technique in the surgical repair of more than 100 patients with hiatal hernias since 1942 Several factors however regarding both the etiology and surgical treatment of hiatal hernias should be further stressed One of the factors responsible for development of a hiatal hernia is the presence of an atrophic or redundant diaphragmatic esophageal ligament This ligament was first described by Laimer in 188 It arises on the under surface of the diaphragm divides into two limbs and the ascending one goes through the hiatal opening and attaches to the esophagus It is the antagonist of the longitudinal musculature of the esophagus and normally prevents the stomach from herniating into the chest upon esophageal contraction I believe that after the redundant hernial sac and ligament are excised this ligament should be again sewn to the esophagus during the reconstruction of this area

In addition to the above as the surgeon explores patients with hiatal hernias it will be noted that the herniated stomach is invariably anterior In my experience there appears to be considerably less diaphragmatic muscle posteriorly between the esophageal and aortic hiatus than what one encounters normally and this is a definite factor in producing the enlarged esophageal stoma This is why it is important to approximate the crura posteriorly by two to three sutures and fashion a new diaphragmatic shelf between these two hiatal openings This in itself will completely reduce the size of the enlarged esophageal stoma

DR R A RASMUSSEN Grand Rapids —I rise simply to mention a maneuver which Dr Harrington and others have used We have used it with success and we feel that it may be of some importance That is to open the diaphragm more than was shown and to suture the cardia of the stomach to the under surface of the diaphragm thereby anchoring it at that point

DR ROBERT M JANES, Toronto —I am sorry Dr Harrington is not here, but I think someone ought to say that it is the principle and the adequacy of the repair that are important and that a satisfactory repair can be accomplished through an abdominal approach as well as through a thoracic approach When there is an associated abdominal condition it may be worth while to be familiar with an abdominal as well as a thoracic approach

I was interested in Dr Sweet's remarks about fascia It recalls a rather amusing incident to me I think perhaps I published a report about the first repair with fascia it was a long time ago when my then chief Dr Gallie was unfamiliar with the approach through the chest I opened the chest he repaired the diaphragm with fascia and then I closed the chest in this very complicated operation

DR LAM (Closing) —Dr Kenney and I appreciate the discussion Dr Adams' case was very interesting and Dr Johnson's was especially so since we have come to believe that this disease is one of rather obese women in their 50's rather than in the newborn infant Dr Sweet's experience of course is classic In our attempt to call attention to the posterior part of this hernia we have more or less de-emphasized the fact that there is a portion of the peritoneal sac anteriorly Our first illustration showed the herniated structures after they had been partly dissected out Since we do not open the peritoneum and pay no attention to the sac we sometimes do not know whether or not a sac is present

Dr Kay mentioned the Allison sutures Of course we use these giving some attention to the so-called phrenoesophageal ligament by the placement of several stitches which approximate the esophagus to the diaphragm We appreciate the remarks of Dr Rasmussen and Dr Janes

It has been our feeling that too much attention has been paid to the peritoneal sac and that surgeons have become fatigued from trying to suture this very friable sort of material If one conserves energy and neglects this sac giving special care to the posterior sutures better results may be expected

MUSCLE WALL TUMORS OF THE ESOPHAGUS

RICHARD H SWEET, M D , LAMAR SOUTTER, M D , AND CARLOS TEJADA
VALENZUELA, M D (BY INVITATION)
BOSTON, MASS

DURING the past ten years, as the techniques of esophageal surgery have improved, there has been a steadily increasing interest in esophageal tumors The benign neoplasms and the sarcomas of the esophagus reported in the literature have been completely summarized a number of times[1 5] It would be redundant to repeat here what has been carefully recorded before Instead, this paper deals primarily with our own series of twenty benign and two malignant muscle wall tumors observed over a twenty-year period The pathologic considerations clinical symptoms, and surgical therapy of these growths are discussed and correlated as far as possible with those previously reported

CONSIDERATIONS OF PATHOLOGY AND GROWTH

Esophageal tumors can be divided according to the layers in which they arise Carcinomas and certain polyps arise primarily from the mucosa Cysts, certain sarcomas, pedunculated fibromyxomas and lipomas are among those which grow in the submucosa Leiomyomas, neurofibromas, fibromas, fibromyomas, leiomyosarcomas, fibrosarcomas and rhabdomyosarcomas originate in the muscularis

1 *Benign Tumors*—The benign muscle wall tumors have little to distinguish them one from another on the basis of their clinical behavior They are often difficult to distinguish microscopically because of a similarity of cellular pattern unless special smooth muscle-cell stains are employed In reviewing the slides of the tumors presented in this series, new sections were cut from many and both Masson and phosphotungstic acid stains were used for more precise histologic identification On the basis of these studies, seventeen of the twenty benign tumors presented here were found to be leiomyomas*, two were diagnosed as neurofibromas, and one was identified as a fibromyoma Two which had previously been called neurofibroma were firmly established as leiomyomas It is of some interest that one of these has repeatedly appeared in various articles as a neurofibroma excised by Dr Churchill[6] Actually, it was probably the first leiomyoma of the esophagus to be removed surgically in this country

All of these benign growths are firm, well-circumscribed, but not necessarily encapsulated tumors Although they may become firmly adherent to surrounding tissues, they are not invasive They occasionally show areas of metaplasia and possibly can develop malignant degeneration One tumor in

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Read at the Thirty third Annual Meeting of The American Association for Thoracic Surgery San Francisco Calif March 27 28 and 30 1953

*Two of these tumors have been reported from clinicopathologic conferences at the Massachusetts General Hospital but are not included in any series of cases reported to date our series had become partially cystic; two more had become partially calcified. At least six tumors have been reported in the literature as showing calcification.[7] Ulcerations of the mucosa over a tumor are rare unless it extends into the stomach. One of our patients had multiple small esophageal ulcers and a large crater partially in the stomach and partially in the esophagus. Kenworthy and Welch,[8] Adams and Hoover,[9] and Cornell and his associates[10] have reported finding ulcers which penetrated into leiomyomas. Bryant[11] reported an ulcer associated with a leiomyoma. Adams' case was the only one in which the ulcer did not occur at the lower end of the esophagus.

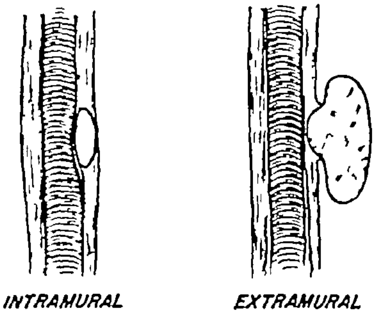
BENIGN TUMORS
ASYMPTOMATIC

Fig. 1

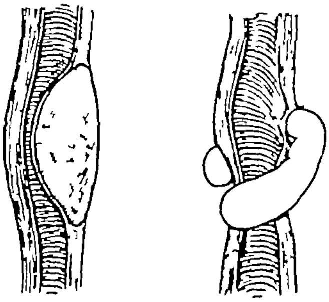
BENIGN TUMORS
SYMPTOMATIC

Fig. 2

Fig. 1.—Diagrammatic sketch of two types of benign muscle wall tumors of the esophagus which rarely cause symptoms.

Fig. 2.—Diagrammatic sketch of two types of benign muscle wall tumors of the esophagus which cause symptoms. The one shown on the left is intramural submucosal and compresses the esophageal lumen. The one on the right is extramucosal, but has caused a small traction diverticulum of the mucosa. Its encircling arms have caused some obstruction of the esophagus.

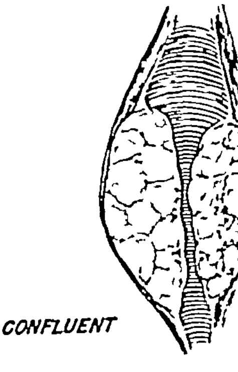
BENIGN TUMOR

Fig. 3.—Diagrammatic sketch of benign muscle wall tumor of the esophagus appearing in a large confluent submucosal mass causing partial obstruction.

As in the uterus, leiomyomas of the esophagus can be single, multiple, simple, nodular, bosselated, or lobulated. Multiple benign tumors were found among four of our patients. Multiple tumors were found in nine different individuals in the series of cases collected by Rose.[4] Carlmenson and Clagett[1] removed two at one operation. Cornell, Lyons, and others[1, 14] have reported them. Sixteen of our twenty patients had single tumors. Of these, six were nodular, bosselated, or lobulated. Although these types of growth as a rule do not give rise to symptoms different from those of the simple ones, their excision can be much more difficult. The reason is that they often present multiple adherent projections of tumor among the muscle fibers, so that considerable muscle damage is entailed by their removal. In one of our patients a horseshoe-shaped tumor was found lying outside of the lower end of the esophagus. It caused dysphagia by external constriction. A similar encircling tumor arising at the same level and causing dilatation of the esophagus was reported by Eberth in 1868.[15] Two more are listed by Rose.[4]

Size is the most important single factor in the production of symptoms by these growths. Although Oshawa[16] excised a myoma only 1 cm. in diameter because it caused symptoms, the smallest of our twelve symptomatic growths measured 3 cm. in diameter. Most of our tumors treated surgically were over 5 cm. in diameter. Most of the surgically treated tumors reported in the literature have been at least 3 cm. in diameter. Three of our tumors occupied the entire lower third of the esophagus. Harrington[17] resected a similar tumor. The largest of ours weighed 675 grams. Schnug[7] removed one weighing 632 grams. Other large tumors have been reported.[4] Large tumors do not always cause symptoms. This is particularly true of those which lie outside of the esophageal wall and are connected to it only by a pedicle which extends through to the submucosa. Two such tumors in our series, measuring respectively, 4 and 5 cm. in diameter, were found at autopsy. No evidence of symptoms related to their presence could be found in the patients' histories. These extramural tumors, if they lie freely in the mediastinum or abdominal cavities and neither press on surrounding organs nor pull on the esophagus, can be completely asymptomatic. Miller found such a one measuring 6 inches in length at the autopsy of a young man.[18] It lay in the abdominal cavity. Daniel and Williams[19] removed a leiomyoma which measured 13 cm. in its greatest diameter from the mediastinum of a woman who had no complaints. Other extramural tumors have caused symptoms, however, as did one of ours.[17, 20]

Most of the benign muscle wall tumors remain beneath the muscle. They cause pain, dysphagia and digestive symptoms as they grow larger because of the pressure they exert on the muscularis and the esophageal lumen. As they become larger, they tend to encircle the lumen. The muscularis over them gradually thins into a tense, hard, densely adherent sheath from which it is often impossible to dissect the tumor free. This led to esophageal resection in two of our cases and one reported by Chi and Adams.[21]

Diverticula have been found associated with benign tumors in a number of instances. Four have been reported as occurring in autopsy specimens.[4, 22] One in our series was found in conjunction with an extramural tumor. Three other surgeons have noted the presence of diverticula associated with surgically treated leiomyomas.[7, 17, 20] The possibility that the weight of an extramural tumor could exert a traction effect through the attachment of its pedicle was suggested by Hoyne and Rogers.[20] Certainly an extramural tumor of sufficient size, unsupported by surrounding structures, would draw the muscularis outward and downward at the site of its attachment, creating a mucosal *pocket* This was apparently the mechanism involved in our case

2 *Sarcomas* —Considerable difference of opinion exists among pathologists as to the classification of sarcomas of the esophagus The German pathologists[2] [3] have divided them into two main groups polypoid lesions and diffuse, infiltrating ones The only true muscle wall sarcomas are the leiomyosarcomas, fibrosarcomas, and rhabdomyosarcomas These exist usually in the form of rough, polypoid tumors Their identification depends on the use of smooth muscle stains Our two specimens were carefully studied and fresh slides were made The previous diagnosis of leiomyosarcoma and rhabdomyosarcoma, respectively, were confirmed The leiomyosarcoma, which has already been reported,[12] was a diffuse, infiltrating lesion occupying a third of the esophagus It was ulcerated and had metastasized to the regional lymph nodes The rhabdomyosarcoma was a polypoid growth 6 5 by 4 by 2 5 cm in size, attached to the muscle wall by a stalk 6 5 cm long and 0 5 cm in diameter It projected into the lumen and was covered with hemorrhagic tissue It had not metastasized

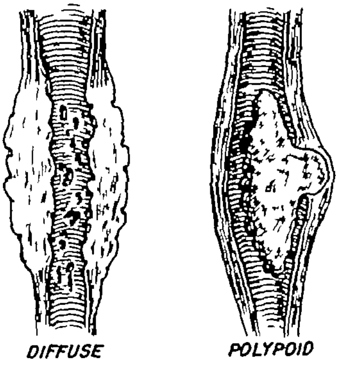

Fig 4 —Diagrammatic sketch of the two major types of muscle wall sarcomas of the esophagus That on the left is diffuse and infiltrating with a rough surface. That on the right is a localized irregular polyp

Although sarcomas arising in the mucosa and submucosa of the digestive tract are usually rapidly growing and highly malignant, leiomyosarcomas are characterized by slow growth, long duration of symptoms, and a low incidence of local and distant metastases[23] The time from onset of symptoms to death in our case was twelve years, which gives rise to the conjecture that the original tumor might have been benign

The literature is very scanty regarding malignant esophageal muscle wall tumors A number of the tumors described in the literature are diagnosed in terms which leave much doubt as to their true histology Little is to be gained, therefore, in discussing them Three leiomyosarcomas have been successfully resected[1] [14] [24] Two were polypoid and one was a nodular diffuse tumor In two cases there was no evidence of metastases, in the other, no statement was made concerning them Thorek's[2] rhabdomyosarcoma, like our own, was polypoid and had not spread The fibrosarcoma removed by Clark[25] was polypoid and showed no metastases That removed by Brea[26] was submucosal, well circumscribed and indistinguishable from a leiomyoma roentgenographically The polypoid tumors tend to become necrotic and to bleed Clark's tumor apparently broke off and was swallowed early in its course and then grew out again Garlock's[14] tumor broke free from its slender pedicle at the time of operation

INCIDENCE AND SITE OF ORIGIN

Although many benign esophageal tumors have been reported in the literature, we have no studies that might reveal the true incidence of benign muscle wall tumors Autopsy findings are inconsistent and inadequate Thirty-three of these tumors were found in 7 459 autopsies at the Mayo Clinic[27] Eleven benign growths were reported from 6 301 autopsies at the University of Chicago clinics[28] No leiomyomas were found in 4 000 autopsies at the Vanderbilt University Hospital[19] Only four muscle wall tumors were found in 13,000 autopsies at the Massachusetts General Hospital At the same time there were four instances in which these tumors were discovered in conjunction with but quite separate from carcinomas in a few hundred surgically resected esophaguses Pathologists when performing autopsies are not likely to make a detailed search for neoplasms in apparently normal organs Meissner, at a time when leiomyoma of the stomach was believed to be rare carried out extremely careful examinations of fifty post mortem stomachs selected at random He found leiomyomas in forty six out of fifty stomachs so studied[29] There is no reason to believe that these lesions exist in the esophagus with similar profusion but certainly we would have a better idea as to their occurrence if someone were to carry out studies by Meissner's technique in a few hundred autopsy specimens

Esophageal muscle wall sarcomas are extremely rare Because the histologic diagnosis is uncertain in all but the most recent literature, we have only a very small amount of material upon which we can base any figures In general their occurrence in this organ is less frequent than in the remainder of the digestive tract Corner and Fairbank[30] found that among 175 sarcomas of all kinds in the alimentary canal only 8 per cent had arisen in the esophagus In the past twenty years, forty-six patients have been operated upon for removal of benign muscle wall neoplasms of the esophagus In the same period we have reports of seven muscle wall sarcomas which were resected and five more which were not Sarcomas as contrasted with benign tumors usually produce symptoms and are seldom so insignificant as to be overlooked at autopsy

Among the twenty patients in our series who had benign tumors, the growths were found in the lower esophagus in thirteen instances, in the middle in five, and in the upper third in two The fact that the distribution is similar to those previously reported serves to indicate that these tumors may occur anywhere but do so predominantly in the lower esophagus

Sarcomas of all types are found most frequently in the lower portion of the esophagus[2, 3] The leiomyosarcoma in our series occupied the entire lower third. The rhabdomyosarcoma, which has been previously reported, occurred just below the aortic arch.[31] Of the tumors reported recently, about which the pathologic diagnosis is reasonably certain so that they are subject to classification, Harrington's leiomyosarcoma lay in the lower third, as did a second inoperable tumor in his series.[24] Resano and Hojman's[1] leiomyosarcoma lay in the cervical esophagus as did that of Menne and Buge.[33] Garlock's[14] lay in the middle third, that of Pennes and the one reported by French and Garland[34, 35] in the same area. Clark's[25] fibrosarcoma grew in the upper esophagus, Brea's[26] was found in the lower third. Dvorak's[3] rhabdomyosarcoma was found in the upper third. Thorek's[2] lay just below the arch of the aorta.

AGE AND SEX

The four benign tumors in our series found at autopsy were apparently asymptomatic. Two were in men, two in women, the ages being 30, 49, 64 and 72 years, respectively. From our knowledge of uterine fibroids it may be assumed that these tumors can exist without evidence of growth for many years. It is therefore impossible to say whether these tumors were of recent origin or whether they had existed in a quiescent state for a large portion of the patient's life. Of the four found coexistent with carcinoma three were in men and one in a woman, the ages of the patients were 56, 63, 65 and 67 years, respectively.

Of the twelve patients who had symptomatic benign tumors, seven were men and five women. The youngest was 19 years, the oldest 67 years, the average age was 41.2 years. The length of time which these patients had noted symptoms, however, was from three months to twelve years, with an average of a little over four years. The average age at onset of symptoms was 37.1 years. Myers and Bradshaw,[5] in 1951 made a survey of some twenty-nine cases of benign muscle wall tumors of the esophagus treated by surgery (excluding Churchill's case which is included in our series). Seven more have appeared in the literature, including one of theirs. The age range of this group of thirty-six patients was from 14 to 66 years, with an average age of 41.6 years. The ages of the patients at the time of surgery in our series are very similar to those previously reported. The average age is lower than that of patients suffering from malignant neoplasms of the esophagus (Table I).

TABLE I. BENIGN TUMORS. AGE AT TIME OF SURGERY OF 47 SURGICALLY TREATED PATIENTS

	THIS SERIES 11 CASES	PREVIOUSLY REPORTED 36 CASES
Minimum	19	14
Maximum	67	66
Average	41.2	41.7

The sex division among the patients reported in the literature is 19 men and 17 women (Table II). Our own series of eleven patients treated surgically was comprised of six men and five women. This makes a total of forty-seven patients if our series is added to the literature, twenty-five of whom were men

TABLE II. BENIGN TUMORS: SEX OF SURGICALLY TREATED PATIENTS

	THIS SERIES	PREVIOUSLY REPORTED	TOTAL
Men	6	19	25
Women	5	17	22
Total	11	36	47

and twenty-two of whom were women. Judging by this small group of cases there seems to be little difference in the sex incidence of benign muscle wall tumors.

Although the average age of patients with sarcomas of all types of esophageal origin has been reported to be the same as that of carcinoma,[3] the average age of the seven patients who have had malignant muscle wall tumors removed surgically (including our own) was 56.7 years, with a range of 43 to 78 years. Dvorak's[3] patient with a leiomyosarcoma was only 27 at the time of death and the tumor could have been removed surgically had modern techniques been available. For esophageal sarcoma in general, the incidence among men as compared with women is three to one. *Among the patients with malignant muscle wall tumors diagnosed in recent years, of which the histologic classification is reasonably certain and the sex has been recorded (including our own cases) there have been seven men and four women.*

The rhabdomyosarcoma in our series occurred in a woman 78 years old who had had symptoms for four months. The leiomyosarcoma occurred in a man of 61 who had had symptoms for twelve years.

SYMPTOMATOLOGY

1. *Benign Tumors.*—Among our patients and those whose symptoms have been described in the literature there is no consistent common symptomatology of benign esophageal wall tumors. There are, however, three general classes into which the symptoms which have been noted may be said to fall. These are *pain, dysphagia* and *digestive symptoms*. In considering the benign lesions we confined our study to the tumors diagnosed surgically, twelve in number, eleven of which were operated upon (Table III). The tumors found at autopsy had apparently caused no symptoms. The four found in conjunction with carcinomas could not be properly evaluated.

Pain was a prominent symptom among nine out of twelve of our patients. It was of the type ordinarily associated with lesions of the esophagus. It was either substernal or epigastric, and usually it radiated. The areas of radiation varied considerably but included the back, scapula, shoulder, neck, or even down either arm. Deglutition seldom produced pain immediately, but in most instances the pain was related in some way to eating although not directly with the act of swallowing. In four of these patients the discomfort bore so little association to meals that they were suspected of having cardiac disease, for which three were actually treated. It should be noted that two of these patients and one other, who had pain but was not suspected of having a cardiac disorder, had hiatus hernias in addition to their tumors. Seven of these patients had pain of sufficient severity to warrant the statement that it was their chief complaint.

TABLE III BENIGN TUMORS COMPARISON OF CHIEF COMPLAINTS OF PATIENTS TREATED SURGICALLY*

	OUR SERIES	REPORTED CASES	TOTAL
Pain	6	8	14
Pain and dysphagia	1	5	6
Dysphagia	3	6	9
Digestive symptoms	1	9	10
Other (Mostly respiratory)		4	4
None		4	4
Total	11	36	47

*This table includes both our series and cases of benign muscle wall tumors of the esophagus reported in the literature. Most of these patients had several complaints

Dysphagia was found among ten of these patients. Their complaints varied from a rare one of food sticking occasionally to a constant inability to swallow solid food. There was no evidence of even temporary complete obstruction among any of these patients. Only two required a consistently modified diet. Six, however, by giving a history of weight loss, presented concrete evidence that obstruction had interfered with their alimentation. This weight loss varied from ten to twenty-eight pounds and averaged fourteen pounds. Three of these patients presented dysphagia as a chief complaint. In addition another had experienced an almost exsanguinating hemorrhage immediately prior to his hospital entry.

Digestive Symptoms were interesting because it is difficult to correlate them with esophageal lesions. They were characterized by gas, eructations, heartburn, nausea, vomiting or postprandial distress. These symptoms were presented by five patients. Two others, who gave a history of ulcer proved by pathologic examination of the stomach or by roentgenogram, had similar symptoms but are not included. These digestive complaints were prominent ones as given by these patients, but in only one did they form the basis of his chief complaint. This particular patient also complained of occasional dysphagia. The tumor lay behind the arch of the aorta. He obtained good symptomatic relief from surgery.

In summary, the chief complaint was esophageal pain in seven patients, dysphagia in three, digestive symptoms in one, and massive hemorrhage in one. Only three patients had complaints falling into all three of the major groups of symptoms.

The length of time which these symptoms had been present was on the whole consistent with what one would expect of benign lesions. The shortest history of symptoms was three months, the longest twelve years, the average four and one-half years. The complaints were seldom constant or of gradually increasing intensity, but were usually intermittent and of variable severity.

Reviewing histories reported in the literature is not as revealing as talking to patients or studying a detailed hospital record, insofar as the interpretation of symptoms is concerned. A rough idea as to the symptomatology of these benign tumors can be obtained, however, by listing the chief complaints of the patients. These are presented in Table III. Briefly, pain alone was the chief complaint among eight of the thirty-six patients so far reported, pain and dysphagia together were found in another five, dysphagia alone in six more, digestive complaints in nine, other complaints (mostly of a respiratory nature) in four, and no symptoms at all were found among the remaining four patients. Dr. Churchill's patient is included in our series and not among those reported previously.

2. *Muscle Wall Sarcomas.*—In general the symptomatology of the esophageal sarcomas closely parallels that of the squamous cell carcinomas. There are, however, some distinguishing differences, as other writers have previously remarked.[2, 3, 14] The first of these differences is that pain, which is rarely presented as a symptom of carcinoma, is a conspicuous complaint among patients suffering from muscle wall sarcomas. Our patient who had a rhabdomyosarcoma had considerable pain. Seven other authors have described this finding.[1-4, 24, 33, 34] The leiomyosarcoma in our series, one of those reported by Harrington,[24] and the fibrosarcoma described by Clark[25] are conspicuous exceptions to this rule as they apparently caused no pain.

Marked weight loss, inconsistent with the degree of esophageal obstruction, is another outstanding symptom of muscle wall sarcoma. Our patient with the leiomyosarcoma lost fifty pounds, the other patient lost twenty, yet both patients were capable of swallowing sufficient amounts of nourishing fluids to maintain their weight. Clark's patient had lost thirty pounds, Garlock's forty, and Dvorak's forty, yet none of these patients had sufficient obstruction to prevent an adequate intake.

Dysphagia is the principal symptom of all patients suffering from sarcomas, but in the cases of muscle wall sarcoma it rarely reaches the degree associated with the stenosing carcinomas. Regurgitation of foul mucus was a prominent complaint of our patient whose leiomyosarcoma had ulcerated. Regurgitation and salivation have been reported as symptoms previously.[1, 2, 24] As these tumors often become necrotic and bleed, both anemia and tarry stools have been found associated with them.[3]

DIAGNOSIS

1. *Benign Tumors.*—It is obvious from the multifarious symptoms associated with benign tumors of the esophageal muscularis that the patient's history is of little help to the surgeon in making a diagnosis. Neither is a physical examination. If the tumor is confined by the muscle wall and protrudes with a smooth unbroken curve into the lumen, a roentgenogram after a swallow of barium may give a picture typical of a benign tumor.[32] As the barium passes evenly over the lesion into the normal esophagus below, it becomes apparent that the mucosa is intact. The unroughened continuity of the mucosa in the region of the growth demonstrated by such means helps to distinguish the extramucosal lesions from destructive growths involving the epithelial layer. Smooth indentations in the tumor mass are indicative of bosselation, lobulation, or multiple growths.

The difficulty of interpreting such findings has been pointed out by Schatzki and Hawes[35] who demonstrated similar defects produced by lymph nodes, mediastinal structures, and extramural neoplasms All of the single lesions in our series were identified roentgenographically as extramucosal benign tumors The presence of ulceration renders diagnosis more difficult

Small intramural growths, of less than 1 cm in size, frequently escape the notice of the roentgenologist Very large tumor masses which angulate the esophageal wall and distort the lumen over a considerable area sometimes remain undiagnosed preoperatively The huge tumor in our series which gave this appearance had been called "cardiospasm" for years The appearance of dilatation above an area of constriction in the lower esophagus has led to this confusion before[16, 30] Our other two large tumor masses were correctly identified by roentgenograms

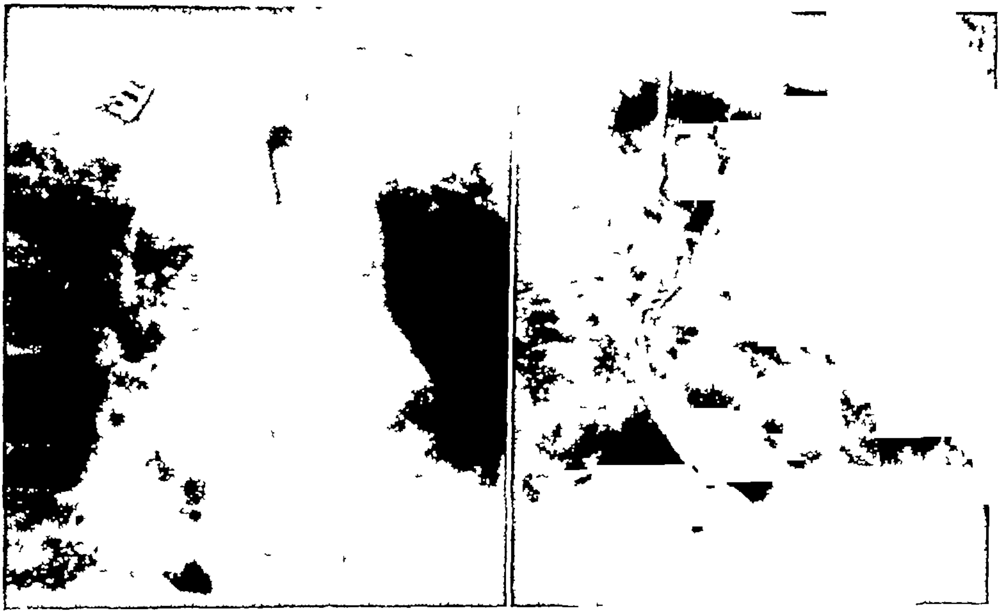

Fig 5—Lateral and posteroanterior views of roentgenograms of a simple submucosal benign muscle wall tumor of the esophagus after a swallow of barium showing its smooth outline and projection into the lumen

Extramural growths without sufficient attachment to the muscle wall to cause distortion usually defy identification as esophageal tumors Those masses which are accompanied by traction diverticula, however, should be suspected of being muscle wall tumors

Esophagoscopy has been frequently employed in the study of these lesions If the esophagoscope can be passed down to and past the lesion so that the endoscopist can be reasonably certain that he has viewed an entirely intact mucosa, he can assure the surgeon that the tumor is not a carcinoma It is impossible, however, by this means to identify positively either the various types of benign tumor or noninvasive sarcoma of the muscle wall

Endoscopic biopsy of these lesions through an intact mucosa is seldom fruitful potentially dangerous, and renders subsequent enucleation without contamination impossible Five of our patients who had symptomatic tumors were esophagoscoped Biopsies were obtained in four One of these showed a leiomyoma two produced no abnormal tissue One was incorrectly diagnosed as a carcinoma

In a number of instances reported in the literature esophagoscopy without biopsy was helpful in confirming the presence of an apparently benign extra-

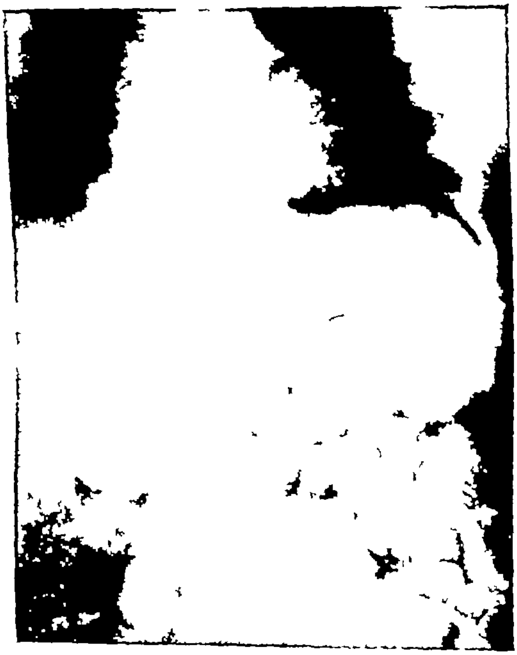

Fig 6 —Roentgenogram of a large mass of submucosal confluent leiomyomas showing angulation of the esophagus.

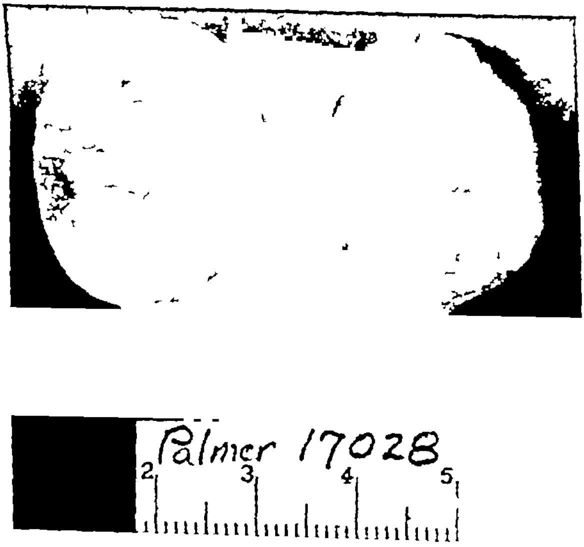

Fig 7 —Simple leiomyoma enucleated from the esophageal wall because it had caused dysphagia.

mucosal lesion[9, 10, 17, 40]. Biopsy has failed to obtain tumor in some cases because of the thickness of the overlying esophageal wall[39, 41, 42].

Benign muscle wall tumors should be kept in mind as a diagnostic possibility in patients of all ages and both sexes who have epigastric or chest pain, dysphagia, or digestive symptoms. If careful roentgenographic studies are made, the diagnosis will often be apparent. Observation esophagoscopy is helpful in ruling out tumors which involve the mucosa.

2. Sarcomas.—The diagnosis of muscle wall sarcoma of the esophagus has not always been made prior to surgical resection or autopsy in the past. The presence of a muscle wall sarcoma should be suspected in a patient thought to have a carcinoma when pain accompanying deglutition is a prominent symptom, when weight loss and cachexia are disproportionate to the degree of obstruction, and when a roentgenogram demonstrates a polypoid tumor. This is particularly true if the symptoms are of long-standing. The leiomyosarcoma in our series was undiagnosed until the tumor was studied microscopically after autopsy. The rhabdomyosarcoma was identified after resection.

Biopsy through the esophagoscope is the best means of establishing the diagnosis preoperatively. The first successful identification of a sarcoma by this means was made by von Hacker in 1903[43]. Among the cases reported in the recent literature at least six such successful biopsies are recorded[1, 3, 14, 24, 25]. In four more including one of our own, biopsy specimens were wrongly diagnosed as carcinomas[2, 33, 35]. The reason for failure has been the presence of hemorrhagic necrotic tissue covering the tumor. In order for the biopsy specimens to be adequate for pathologic identification, they should be large and deep.

THERAPEUTIC CONSIDERATIONS

1. Benign Tumors.—Most of the benign muscle wall tumors reported so far have been asymptomatic. Four of ours found at autopsy certainly were so and the four found in esophageal segments resected for carcinoma apparently caused no trouble. All of these tumors were either small or extramural. Although these asymptomatic lesions may not grow for years and appear to be harmless their positive identification as benign can be established only by biopsy or excision. It has been necessary occasionally to remove such tumors in order to determine their exact nature when they were roentgenographically indistinguishable from malignant neoplasms of the mediastinum.

Small tumors causing symptoms should be removed as soon as possible to avoid the surgical difficulties incurred by their becoming so intimately adherent to the esophageal wall or of growing to such a size that they can be removed only by esophageal resection.

Simple enucleation without entering the mucosa, followed by reconstruction of the esophageal wall, is the treatment of choice. This procedure was carried out on seven of our patients, one of whom died postoperatively of anesthesia complications. Nineteen tumors reported by Myers and Bradshaw[7] were removed in a similar fashion, excluding Dr. Churchill's case

One of these patients died postoperatively. Since their summary was written, four more tumors have been reported as successfully enucleated by Engelking,[40] Tuttle,[41] Guetgemann,[42] and Myers and Bradshaw.

Two of our patients had tumors which were excised along with small segments of mucosa. They both made uneventful recoveries. Two similar successful cases are listed in Myers and Bradshaw's summary. Westerborn[43] has since reported another.

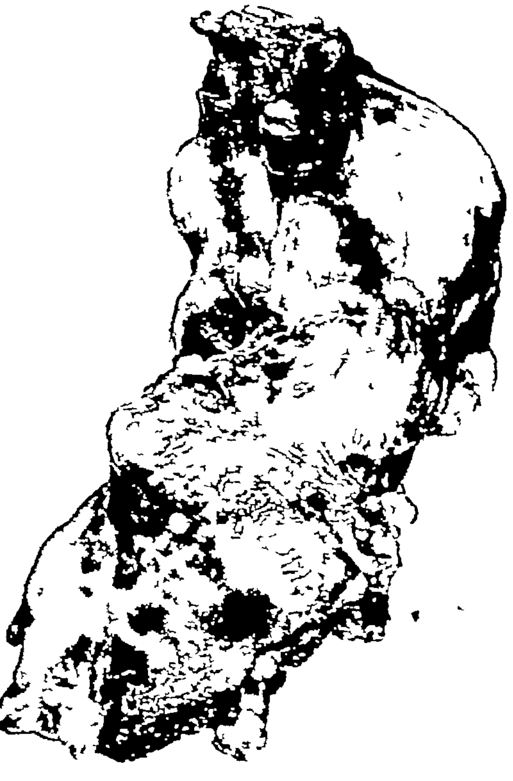

Fig 8

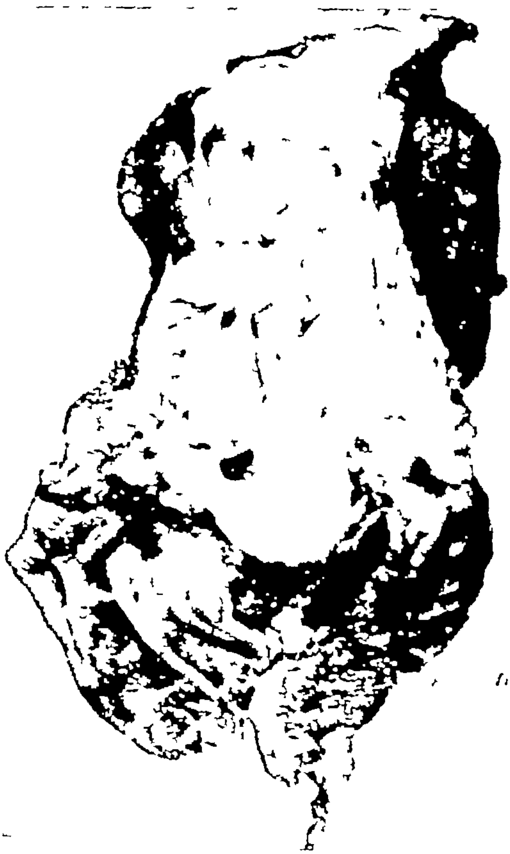

Fig 9

Fig 8.—External appearance of a surgically resected specimen of the lower esophagus and stomach containing multiple confluent leiomyomas.
Fig 9.—The intraluminal appearance of the specimen shown in Fig 8.

In our cases, three of the tumors were approached from the right side of the chest and six from the left. If the tumor preoperatively appears to be simple and not so large or extensive that the muscle coat over it cannot be preserved, the approach can be made as a matter of operative convenience depending upon the position and projection of the tumor. If doubt exists as to the possibility of local excision, however, because of the size or the extent of the lesion, the surgeon should prepare preoperatively for esophageal resection. In one case reported in the literature enucleation was impossible when the tumor was approached from the right and a second operation was necessary on the left in order that the esophagus could be resected.[21] In another case the attempted enucleation of an extensive tumor ended in failure.[45]

Two of our patients required resections of the esophagus in order to remove the tumor mass. In one of these the diagnosis was established preoperatively by roentgenogram and a resection was planned preoperatively. The other patient had been treated unsuccesfully for esophagitis and what was termed "cardiospasm" in a number of clinics for nine years. He entered the hospital after an exsanguinating hemorrhage. Previous films had shown evidence of esophageal ulcer. After multiple blood transfusions he was operated upon as an emergency with the true diagnosis unsuspected. The tumor was identified at operation and the esophagus and part of the stomach into which the tumor had intussuscepted were resected. Both of these patients made satisfactory recoveries. Seven resections for benign tumors, with two deaths, have been reviewed by Myers and Bradshaw.[5] Schnug has also reported a successful resection (Table IV).

TABLE IV. SURGICAL TREATMENT. TYPES OF OPERATIVE APPROACH TO BENIGN MUSCLE WALL TUMORS

	THIS SERIES		PREVIOUSLY REPORTED		TOTAL	
	NO. OF CASES	OPERATIVE MORTALITY	NO. OF CASES	OPERATIVE MORTALITY	NO. OF CASES	OPERATIVE MORTALITY
Enucleation	7	1	22	1	29	2
Attempted enucleation	0	0	1	1	1	1
Excision with mucosa	2	0	4	0	6	0
Resection	2	0	9	2	11	2
Total	11	1	36	4	47	5

The technique of esophageal resection is now so well standardized as to require no comment here other than to state that the large resection margins required in cancer surgery are unnecessary in handling benign tumors. Local excision is of more interest. An esophagus which contains a large intramural benign tumor has the appearance of being engorged with a tumor mass. The appearance is somewhat analogous to that of a boa constrictor which has recently swallowed a pig. If the esophagus is freed up, it can be drawn out of the mediastinum so that the area in which the tumor projects may be identified by rotating the esophagus with the hand. A longitudinal incision made over the presenting area of the tumor followed by gentle pressure by the surgeon's hand as it encompasses the esophagus will usually cause the tumor to extrude from the muscularis. If the tumor is adherent to the mucosa or muscle fibers, it can be gently dissected free. If necessary, a small portion of mucous membrane can be excised with it. Care must be exercised to remove the intramuscular pedicle of extramural tumors to avoid the possibility of recurrence. The technique of closure of the esophageal wall has been too well described many times before to warrant comment here.

One of our patients with a huge mass of confluent leiomyomas surgically diagnosed by biopsy through an esophagoscope has not yet had a resection. He did not desire surgery, nor was it deemed advisable once the tumor was determined to be benign. His pain and dysphagia were both intermittent and moderate. His chief difficulty consisted in duodenal obstruction from an active duodenal ulcer which had been present for twenty-five years. The ulcer required immediate treatment which was provided in the form of a transabdominal vagectomy and pyloroplasty. This combination of procedures was elected in order to preserve the full length of the stomach should his esophageal tumor ultimately require resection. In the five years which have passed since this operation, his dysphagia and esophageal pain have not changed. Roentgenographically the leiomyomas have not become more extensive but show signs of increasing calcification. Malignant degeneration has not become evident.

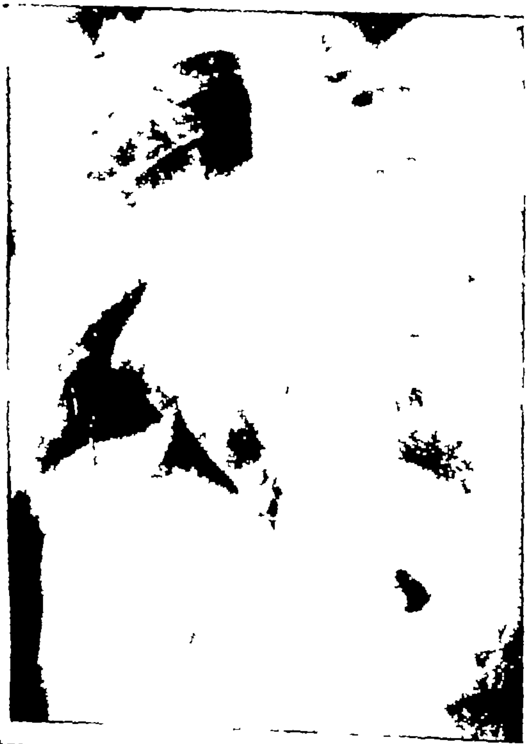

Fig 10.—Roentgenogram of a partially calcified extramural leiomyoma which encircles and partially occludes the esophagus. A small barium-filled esophageal diverticulum lies over the tumor on the left.

Among the forty-seven patients (including eleven of our own) whose benign esophageal wall tumors were treated surgically, the results are as follows. In one patient the tumor could not be removed.[40] She died postoperatively. In another some tumor was left behind.[17] The remaining forty-five patients reportedly had complete removal of their growths. Four of these patients died postoperatively. Four of the remaining forty-one had no symptoms preoperatively. The remaining thirty-seven patients apparently obtained good symptomatic relief from surgery.

2. *Sarcomas.*—Both radiation therapy and surgery have been employed in the treatment of the muscle wall sarcomas. As might be expected in dealing with tumors of muscular origin, radiation therapy has not been successful

The diagnosis in the cases so treated was established by pathologic means as rhabdomyosarcoma[3] in one case and leiomyosarcoma[33, 34] in two, and fibrosarcoma in a fourth.[26]

In reviewing the muscle wall sarcomas treated surgically we have confined our studies to those tumors of which the histologic identification was sufficiently clear so that there could be little question as to the classification of the tumor both as to its site of origin or its cell type. Most of the cases reported in the foreign literature, particularly in articles written more than twenty years ago, despite detailed histologic descriptions, defy identification in terms of our present-day nomenclature. To draw conclusions as to clinical behavior of tumors of which the exact diagnosis is in doubt is misleading. Although the treatment of these unidentifiable sarcomas is not statistically important, it is of considerable historical interest. At the end of the last century and early in this one gastrostomy was frequently performed to combat starvation secondary to dysphagia and obstruction. Tracheotomy was sometimes employed to prevent asphyxia if the lesions involved the pharynx.

Direct attack was first carried out upon cervical sarcomas because of their accessibility. In 1875 Baum[46] excised locally a polypoid sarcoma of the pharynx which extended into the esophagus.[46] Von Hacker[43] resected a muscle wall tumor of the cervical esophagus in 1903. The patient died of pneumonia and metastases three months later. The pathologic description of this tumor we have had translated into English and reviewed by a pathologist who thought that the tumor was probably a fibrosarcoma but could not be certain.[47] Snoy[48] successfully removed a sarcoma of the esophagus and pharynx in 1911.

Because of their inaccessibility, the sarcomas of the thoracic esophagus remained inviolate until Harrington successfully resected a diffuse leiomyosarcoma of the lower third in June, 1945.[24] The rhabdomyosarcoma in our series was resected in July, 1945, and a supra-aortic esophagogastric anastomosis was performed. The patient was an emphysematous, malnourished woman 78 years old with severe arteriosclerotic heart disease. She died of pulmonary infection and cardiac failure on the twentieth postoperative day. No metastases were found either at operation or at autopsy.

Garlock[14] resected a leiomyosarcoma in 1946. The patient was well six years later. Clark[25] successfully resected a fibrosarcoma in 1947. Thorek[2] was able to carry out a successful resection of a rhabdomyosarcoma in 1948. Brea[26] reported enucleating a well circumscribed extramucosal tumor of the lower esophagus in 1948. Although the tumor was believed preoperatively to be a leiomyoma, pathologic section proved it to be a fibrosarcoma. The tumor recurred two and one-half years later, was resistant to radiotherapy, and the patient subsequently died. Resano and Hojman[1] successfully resected a leiomyosarcoma of the cervical esophagus by the Wookey technique in 1951. These cases are outlined in Table V.

Considering the good early results obtained in this small group of cases, surgical resection is the treatment of choice for both diffuse and polypoid muscle wall sarcomas. Palliative resection of carcinoma of the esophagus is

TABLE V. SARCOMAS OF THE ESOPHAGEAL MUSCLE WALL REMOVED SURGICALLY

SURGEON	YEAR	AGE	CHIEF COMPLAINT	TYPE OF TUMOR	DIAGNOSIS	RESULT
Harrington	1945	60	Pain, dysphagia	Nodular and diffuse	Leiomyosarcoma	Recovered
Sweet	1945	78	Pain, dysphagia	Polypoid	Rhabdomyosarcoma no metastases	Died
Garlock	1946	58	Pain, dysphagia	Polypoid	Leiomyosarcoma, no metastases	Well 6 yr later
Clark	1947	43	Dysphagia	Polypoid	Fibrosarcoma	Recovered
Brea	1948	65	Dysphagia	Intramural	Fibrosarcoma, no metastases	Recurred 2½ yr later
Thorek	1948	43	Pain, dysphagia	Polypoid	Rhabdomyosarcoma	Recovered
Resano and Hojman	1951	50	Dysphagia	Diffuse	Leiomyosarcoma, no metastases	Recovered

of proved value in lengthening the life of the patient and rendering his life more bearable by restoring continuity of the alimentary tract and by relieving pain. Palliative surgery for extensive spindle cell sarcomas of the esophageal wall would appear to be justifiable on the same grounds. Salivation and regurgitation of foul mucus were distressing symptoms late in the disease of our patient who died of a diffuse ulcerated leiomyosarcoma, as they have been in cases reported by others. The avoidance of these symptoms is an additional reason for advocating palliative resections.

SUMMARY AND CONCLUSIONS

A series of twenty-two muscle wall tumors of the esophagus has been presented. Twelve of these, one malignant and eleven benign, were removed surgically. A correlation has been made between those previously reported and our observations of the pathologic and clinical manifestations of these growths, their diagnostic characteristics, their treatment, and the results of therapy.

The benign tumors, although distinguishable from one another by careful histologic study, are so closely related in terms of clinical behavior that they may be grouped together. Most small benign tumors are usually asymptomatic, but when they become larger than 1 or 2 cm in diameter, they may cause symptoms if they remain intramural. Extramural tumors can be confused with malignant tumors of the mediastinum, but only produce symptoms by encircling the esophagus or by pressure on adjacent viscera. A presumptive diagnosis of a benign tumor can usually be made roentgenographically. Esophagoscopic examination may help to rule out carcinoma, but biopsy is seldom helpful and may be harmful. The best treatment for symptomatic benign tumors is local excision, but esophageal resection may be necessary if the tumors are large, extensive, or multiple. The mortality of the surgical treatment of benign lesions should be low. The results of such treatment are good.

The primary sarcomas are extremely rare and little is known about them. The experience with surgical removal of sarcoma is small. The diagnosis of these tumors preoperatively depends upon an adequate biopsy. The ideal treatment of muscle wall sarcoma is resection. There is some promise that polypoid sarcomas arising in the muscularis can be cured in a high percentage of cases, as they are slow growing and slow metastasizing

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DISCUSSION

DR RICHARD H MEADE Grand Rapids—This has been a beautiful presentation and my object in arising is not to discuss the total subject In 1946 Dr Kay reported on the benign tumors of the esophagus from Kennedy General Hospital So far as I know, those cases have never been reported by others in speaking of benign tumors Of the two cases we had, both were extramucosal tumors, the first was at the lower end of the esophagus and was readily enucleated without difficulty The second one involved the upper esophagus and also was enucleated without difficulty, so we thought, but the patient later developed aseptic necrosis of the esophagus and died We were not aware at the time of operation that the blood supply was interfered with I should like to ask Dr Soutter and Dr Sweet if tumors in this particular region should be handled in a different way

DR JOHN F HIGGINSON, Portland—I enjoyed the presentation of Dr Soutter and Dr Sweet The question of what to do with the benign variety of these smooth muscle tumors is a difficult one to decide, particularly if the case is further complicated by a multiplicity of tumors, and aside from the question of malignancy which is of course, always present I would like to use a case to demonstrate this particular feature

(Slide) This is the preoperative roentgenogram of a barium swallow in a 30 year old man, whose condition was noticed after a routine chest survey x ray examination showed a large mediastinal tumor in the lower chest which apparently involved the esophagus This picture demonstrates the large tumor of the lower esophagus with obvious distortion of the esophagus and also shows several other tumors above Esophagoscopy was done on two occasions and, as the authors stated, both esophagoscopic examinations were unhelpful At 29 and 35 cm from the upper incisor teeth there were small irregularities in the esophageal mucosa which however, did not yield any particular information There was, of course, lower in the esophagus the deformity one would expect from such a tumor as this large one

(Slide) This gives a rough idea of the general size of the tumor, because this tumor was so large and involved a good portion of the lower esophagus and because there was also a multiplicity of tumors (we were able to palpate the two other tumors in the middle and upper esophagus), we did not feel that we should resect the esophagus in this 30 year old man who had no symptoms except occasional gagging when he swallowed Moreover, the tumor extended out of the esophagus down into the cardia and fundus of the stomach, and it would have required a proximal gastric resection and a distal esophageal resection in order to remove it by resection

(Slide) Accordingly, the tumor was removed by the method described by the authors, and it was rather surprising to find that by tedious dissection it was possible to remove this tumor from within the interstices of the splayed out fibers of the esophagus The only portion of the esophageal wall which was at all still present as true wall was the right aspect of it, and this retained sufficient circulation to permit repair of the esophagus This tumor was 7 by 17 cm, with the tonguelike extension seen here going down to the stomach, measuring 4 by 15 cm The total weight was 645 Gm It was an obvious, usual, typical leiomyoma

(Slide) This is a postoperative roentgenogram showing the normal looking lower esophagus, although you will note there seems to be an esophageal hiatal hernia There was indeed a small one at operation which was repaired This is not a hernia, the radiologist tells us, it is merely the broadened and still rather large lumen of the esophagus which had been originally distorted in a fishtail manner, and then diminished in caliber by the surgery We have not as yet taken out the tumors above, and we are letting a considerable period of time elapse until the circulation has returned below, so that when we bother these we will presumably not injure the esophagus irreparably

DR JOHN H. GARLOCK, New York—We would like to report and put on record for the first time seven cases of leiomyoma from our clinic Three were found incidentally in excised specimens resected for carcinoma Four were operated upon I might say that esophagoscopy preoperatively is of considerable help to the surgeon in arriving at a positive preoperative diagnosis, because the esophagoscopist can tell whether there is intact mucosa over the tumor Under such circumstances biopsy is not advisable Three of the four were diagnosed preoperatively on the basis of the x ray findings and esophagoscopy Three of these were at the lower end, one was in the middle third Two of those in the lower end were extensive almost completely encircling the esophagus and having many ramifications in the musculature It was felt in each instance that in order to effect complete removal and have an intact esophageal lumen, resection would be necessary and this was done One of those at the lower end was excised by enucleation, as was also the one in the middle third All the patients recovered and have remained well

The one case of leiomyosarcoma which was mentioned by Dr Soutter brings up a point in technique of the operation This was a very large tumor, measuring 4 or 5 inches in length, it filled the lumen of the esophagus and felt like a large sausage It was obviously pedunculated During the process of mobilization of the esophagus the tumor suddenly disappeared This was quite disconcerting because we did not know where it went When we incised the diaphragm to mobilize the stomach we found it near the pylorus The temptation was very great to remove it through a gastrostomy incision and terminate the operation, especially since nothing was palpable in the esophagus at what we thought might be the site of the pedicle But we went ahead with resection anyway and it was a good thing we did, because there was infiltration of the wall of the esophagus at the site of the pedicle which extended into the muscularis The tumor proved to be one of high degree of malignancy If we had not done that, I am sure this patient would not have survived for seven years

DR WILLIAM L WATSON, New York—In discussing this presentation of rare esophageal sarcomas by Dr Sweet and Dr Soutter, of course anything we say must be considered additive and of value only from that viewpoint But because malignant sarcomas of the esophagus are so unusual I thought it might be of interest to report our ex perience We have one fibrosarcoma of the esophagus that developed twenty years after radiation of the upper neck over a long period of time for a supposedly benign tumor of the thyroid gland This patient is of interest to us because she had a carcinoma of the breast treated by radical mastectomy, also a carcinoma of the skin developing in the radiated area, and at operation the supposedly benign tumor of the thyroid, which was removed in doing surgery on the cervical esophagus, proved to be a cancer of the thyroid, and the tumor removed from the esophagus was a fibrosarcoma So this woman is the only patient in our series who has had four cancers—each one arising in a different anatomic structure

The important group however, is that comprising the four patients with myosarcoma Those tumors were located as follows one at the thoracic inlet, one at the middle third, and two in the lower third of the esophagus One patient had a local excision and has been well for seven years, two had resections and gastroesophageal anastomoses and are dead, one of local recurrence in four months and metastasis to the liver, and another of disease four and one half years after surgery The fourth patient treated by exploration (excisional surgery was not done) and gastrostomy plus x ray therapy is now alive and has been well for five years

I should like to show a slide of a patient about whom there may be some controversy This is the summary of our cases of cancer of the esophagus In a series of 1,113 there were four leiomyosarcomas, one fibrosarcoma, and one leiomyoma

(Slide) This patient's tumor was the first to be discovered on routine barium swallow carried out on all patients without symptoms who were beyond the age of 40 years She was slightly overweight but otherwise normal I did an esophagoscopy and did not find any evidence of ulceration and thought we were dealing with a benign muscle wall tumor, so no biopsy was taken

(Slide) At operation the tumor, measuring 7 cm in diameter, was easily excised It felt like a benign tumor and I considered it to be so, I took out a small amount of the esophageal wall and was able to do a primary closure Four days later I was informed by our pathologist that this was a malignant tumor

So we have two points to make One is that the pathology varies considerably, and the other is that the pathologist may now look back and say that our one case which has gone seven years without recurrence after local excision must therefore be benign X ray therapy seems to have something to offer and one patient so treated is alive five years after treatment

DR HERMAN MOERSCH, Rochester, Minn —Dr Soutter and Dr Sweet have again presented us with an excellent and instructive paper I should like briefly to discuss the tumors that they have classified as leiomyoma and leiomyosarcoma and try to emphasize some of the more salient points concerning these tumors My remarks are based on a recent review which one of my associates Dr Bruce Johnston, has just completed of all cases of leiomyomas and leiomyosarcomas of the esophagus in which operation was performed and the type of lesion proved microscopically at the Mayo Clinic during the past twenty years

During that period, twenty one patients with leiomyoma of the esophagus underwent operation In seventeen instances, the leiomyoma was limited to the esophagus, and in the four remaining cases the tumor involved the lower end of the esophagus and extended into the cardiac end of the stomach During the same period, five patients having leiomyosarcoma of the esophagus underwent operation It is of interest that fifteen of the patients having leiomyomas limited to the esophagus were men and only two were women The four patients who had leiomyomas which extended into the cardiac end of the stomach were women

With respect to the symptoms of leiomyoma of the esophagus, our experience was similar to that of the essayists In seven of the seventeen cases in which the lesion involved the esophagus alone, the patients were entirely asymptomatic In contrast, in all cases in which the leiomyoma involved both the esophagus and the stomach, the patients had symptoms The same was true of the patients with leiomyosarcoma

Although, as Dr Soutter has pointed out, the diagnosis of leiomyoma of the esophagus can usually be made with relative ease by means of roentgenographic examination and esophagoscopy, occasionally great difficulties are encountered I was especially interested in the remarks of Dr Soutter and Dr Watson concerning the removal of tissue from a leiomyoma through an esophagoscope for microscopic examination I may be wrong, but it is my opinion that it is not advisable to remove a specimen for biopsy from such tumors In order to obtain tissue from the leiomyoma it is necessary to bite through normal esophageal mucosa which covers the tumor Should the patient be operated on soon after such a specimen has been removed, and the tumor shelled out the small hole in the esophageal mucosa made by removal of the specimen might escape detection and act as a possible source of mediastinal infection

As stated previously, the diagnosis of leiomyoma is not always an easy matter and at times these tumors cannot be shelled out but must be removed by means of resection A case in point at the Mayo Clinic was that of a young woman who suffered from dysphagia The roentgenogram of the thorax showed the *entire lower portion of the right side of the* thorax to be infiltrated Roentgenograms of the esophagus showed it was displaced to the right wall of the thorax The correct diagnosis was not established until operation when it was found that the patient had a huge leiomyoma that involved the lower end of the esophagus and the cardiac end of the stomach completely encircling both organs and displacing the esophagus to the right wall of the thoracic cavity It was impossible to shell out the tumor, but resection was performed by Dr Harrington with most satisfactory results

DR LEO J KINNEY, Detroit —I have been tremendously interested in the paper of Dr Sweet and Dr Soutter and also in the remarks of the other discussants Within the past year I encountered a benign tumor of the esophagus which is probably the "Paul Bunyan" of all esophageal tumors I would like to present this case

(Slide) This is a 17 year old boy who had dysphagia for twelve years He had been treated at several medical centers as a case of congenital shortening of the esophagus with cardiospasm The slide illustrates the preoperative x ray study Shortly after these films were taken he developed complete obstruction of the esophagus

(Slide) This is an artist's reconstruction of the situation The tumor completely encircled the esophagus In order to remove it we had to open both the right and left chest The tumor was adherent to the right lateral chest wall and to the right diaphragm

(Slide) *This illustrates the extent of resection* The lower two thirds of the esophagus, the upper third of the stomach, and the spleen were removed An anastomosis was made above the aortic arch

(Slide) This shows the tumor itself It measured 19 cm in length, 15 cm in width in the opened condition, and 7 cm in thickness It weighed 1,420 Gm

(Slide) *The final slide shows the postoperative x ray study, four months after operation* The upper segment remains dilated but there was no delay in the passage of barium and the boy is completely free of any swallowing difficulties

DR ROBERT M JANES, Toronto —In asking Dr Sweet to close, I wonder if I might ask him a question One very large tumor that was presented in Dr Soutter's paper interested me, *because I suspect that one of the patients in his table, on which there* was an unsuccessful attempt at enucleation, was one that I helped Dr Shenstone with at least fifteen years ago The unsuccessful attempt, however, relieved the patient's difficulty in swallowing The tumor extended to the diaphragm and the aortic arch and was at least 3 inches in diameter in a young girl 21 years of age The symptoms dated back to childhood She has since married and is well to date with very little change so far as we can determine by x ray examination I wonder if Dr Sweet has any idea of the incidence of malignant changes in these tumors and whether it is ever wise to exercise discretion rather than valor

DR SWEET (Closing) —We were *very hopeful that this paper would stimulate* discussion and presentation of cases, and I can assure you that our expectations have been amply justified There is one preliminary point I would like to make before commenting briefly about the questions brought up, that is that in going over the literature, and this applies to many of the cases mentioned here today, especially that of Dr Janes, Dr Soutter found that the literature was in an almost chaotic state He has made a very earnest effort to find every possible report and case and has read with one or two exceptions of inaccessible journals every article that has been presented that he could find It was interesting, for example, to find that one of our own cases which had appeared in a report previously, appears in the literature as two cases, reported once by the pathologist and once by the surgeon Things of this sort have occurred in many other instances So we have attempted in this paper to bring a little order out of the chaos

To turn to Dr Meade s question first of all I believe that the cases of Dr Meade, Dr Kay, and Dr Daniels were reported in a summary by Drs Myers and Bradshaw in THE JOURNAL OF THORACIC SURGERY in 1951, we must have missed it I cannot answer Dr Meade s question I have no personal knowledge and I do not believe Dr Soutter has either, of why one should encounter necrosis in benign tumors of the esophagus enucleated from any particular segment Of course we are all aware of the segmental nature of the blood supply The only comment I can make about this is that I was consulted once about a patient who had had such an operation done on the upper portion of the esophagus where a fistula had resulted. Perhaps that was another instance of what Dr Meade speaks of

With regard to Dr Higginson s interesting case, of which I was very pleased to hear, I suspect it was much like the one Dr Soutter showed last in our series, a patient upon whom we have not yet operated I must commend him for his exceedingly successful accomplishment We have hesitated to operate upon our patient because of the enormous amount of esophagus involved and as a matter of fact he is getting along quite well as he is There is more than one way of handling such problems

Dr Garlock, I am pleased to see, reported his series, a large one as these cases go I do not agree with Dr Garlock, however, on using esophagoscopy and esophagoscopic biopsy in these cases In fact, I never use it in any case unless I feel that I cannot establish a diagnosis in any other way His mention of the pedunculated nature of the malignant tumor is very important and emphasizes the importance of suspecting malignancy in some of these pedunculated tumors I had a similar case which was reported as an adenoacanthoma with elements of epithelial malignancy as well as smooth muscle malignancy

We are grateful to hear about Dr Watson's interesting group I am sure however, that we would not have included his first case in our report because it was a fibrosarcoma and not a leiomyosarcoma, although it might be difficult to distinguish the two

Dr Moersch's experience is exceedingly interesting and valuable We are pleased to have it presented in the discussion It would seem to me even with his large experience added to it, that we still do not have quite enough cases available to decide what the sex incidence is and why these tumors happen to be more common in one location than another But I certainly heartily agree with Dr Moersch about the inadvisability of obtaining biopsies in these cases, for the reasons he mentions and the technical difficulties and perhaps hazards which might result from previous injury to the mucosa at the time when the operation is to be done

Dr Kenney's case was of interest because one of our large tumors such as his was also treated for a long time with a diagnosis of cardiospasm But he obviously has brought forth the leviathan of leiomyomas

With regard to Dr Janes s suggestion that the unsuccessful attempt at removal might be the one with which he had experience I must say to our embarrassment that we did not know about his case The one that was mentioned by Dr Soutter was reported by Mr Barrett of London The patient died With regard to the possibility of malignant degeneration in leiomyomas, we have no knowledge of that at all I have always thought of these tumors in the same terms as we think of uterine leiomyomas, and of course we are all familiar with the fact that a few of them become malignant, but just how to pick the potentially malignant ones I am sure I do not know

Dr Soutter and I would like to thank all the discussers

REINFORCEMENT OF AORTIC ANEURYSMS BY WRAPPING

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CONSIDERABLE confusion seems still to exist regarding reinforcement of aortic aneurysms by external wrapping or patching. This confusion includes not only the modus operandi of the wrapping but also the nature of the material required and the sterilization of this material to prevent it from losing its irritating properties.

It is necessary to understand that the film employed represents merely a vehicle or structural framework for an irritating chemical which produces the fibrosis. Reinforcement of the aneurysm does not depend upon the tensile strength of the enveloping sheath nor upon the tightness of its application, nor necessarily upon the complete encirclement of the aneurysm. However, the greater the percentage of aneurysm surface covered the more effective the reaction. In clinical practice it is rarely possible to encircle completely large aneurysms which already are eroding into the spine, sternum, or other adjacent structures.

Pierce[1] has reported evidence of Cellophane bands cutting through the aorta of a dog when applied too tightly. An earlier report[2] of experimental work in 1946 indicated that polyethylene film produced a greater fibrous tissue reaction around dogs' aortas than the various types of Cellophane tested. These tests were conducted to determine which type of material produced the greatest fibrosis and constriction, since the literature contained a number of conflicting experimental and clinical reports on the subject. A supposedly inert plastic film called polyethylene was included among the types of Cellophane or cellulose hydrate and acetate. Much to our surprise the most extensive fibrosis was produced by the polyethylene which was said to be 99 per cent pure. Due to trade secrets it was impossible to identify the nature of the contaminant at that time, but Yaeger and Cowley[3] finally discovered it to be dicetyl phosphate and demonstrated its irritating reaction. Considerable confusion arose from two sources. First, the failure to distinguish the plastic film polyethylene from cellulose film known as Cellophane, and second, the different experimental and clinical reactions produced by two different types of polyethylene manufactured by different processes. The melt cast method which is now used almost exclusively produces a completely pure polyethylene which can be left inside the body without causing any reaction.[4] The solvent cast method which was used only experimentally by DuPont during the early stages of development of polyethylene in 1945, introduced dicetyl phosphate as a contaminant on the surface of the film in less than 1 per cent concentration. This type is known as N.Y. 7-14 and represents the one which caused the fibrosis around the dogs' aortas.

Read at the Thirty-third Annual Meeting of The American Association for Thoracic Surgery, San Francisco, Calif., March 27, 28 and 30, 1953.

The inconsistent results obtained with Cellophane would appear to be due to the fact that it is manufactured for the packaging trade rather than the medical profession and is covered with a number of different sizings to meet the demands of self-sealing and vending machines. These sizings seem to greatly influence the tissue reaction but may be lost in the process of sterilization, depending upon the firmness of anchorage.

This same problem of losing the active ingredient or dicetyl phosphate from the polyethylene, has arisen in the process of its sterilization and has undoubtedly reduced its effectiveness when improperly sterilized. Neither dry heat sterilization nor boiling is desirable since polyethylene has a melting point of 120° C. and dicetyl phosphate a melting point of 72° to 73° C. Thus, even though the original shape of the film may be partially retained after boiling a large percentage of the dicetyl phosphate has been lost in the water. Cold chemical sterilization remains as the most practical method and even this may cause loss of phosphate if the wrong solution or if too long a period of immersion is used. Dicetyl phosphate[7] is known to be slightly soluble in cold water and more soluble in alcohol, the rate of solubility increasing with the temperature and concentration of the alcohol. It is also soluble in benzene, toluene, butyl ether, and olive oil.

Analyses of the phosphate remaining on the polyethylene film and the amount lost in the sterilizing medium were made by Todd of the Biochemistry Department of the University of Oregon Medical School after immersing the film in different sterilizing agents for varying periods of time. Polyethylene film soaked for one week in 70 per cent alcohol lost 97 per cent of its dicetyl phosphate. Film soaked for one week in 1:1000 aqueous Zephiran solution lost 92 per cent of its dicetyl phosphate. Film boiled for ten minutes in water lost 40 per cent of its phosphate. Film soaked twenty minutes in 1:1000 Zephiran lost 16 per cent of its phosphate. Soaking the film in a cold aqueous solution of strong bacteriocidal agent for as short a time as is consistent with good aseptic technique appears to represent the best method of sterilizing the material without losing its active principle.

The solubility of dicetyl phosphate in sterilizing solutions and the insolubility of polyethylene in the body led to a search for another combination with opposite physical properties. Gelfoam film was substituted for polyethylene as a vehicle for irritating substances, but the Gelfoam disintegrated so rapidly when brought in contact with tissue juices that it proved to be technically impractical to handle, either as impregnated sheets or as a thin bag containing the powder. Talc, such as was formerly used for surgical glove powder, and powdered asbestos were impregnated on the surface of polyethylene film and a moderately satisfactory reaction was obtained. The perivascular fibrosis produced by talc and asbestos was not as dense as that produced by dicetyl phosphate during the short period of observation of two to four months employed experimentally in these dogs. Asbestos produced a more profuse reaction than did talc.

Injections of dicetyl phosphate in a 9 per cent solution in olive oil, as recommended by Berman and his associates,[6] has been used in inaccessible areas

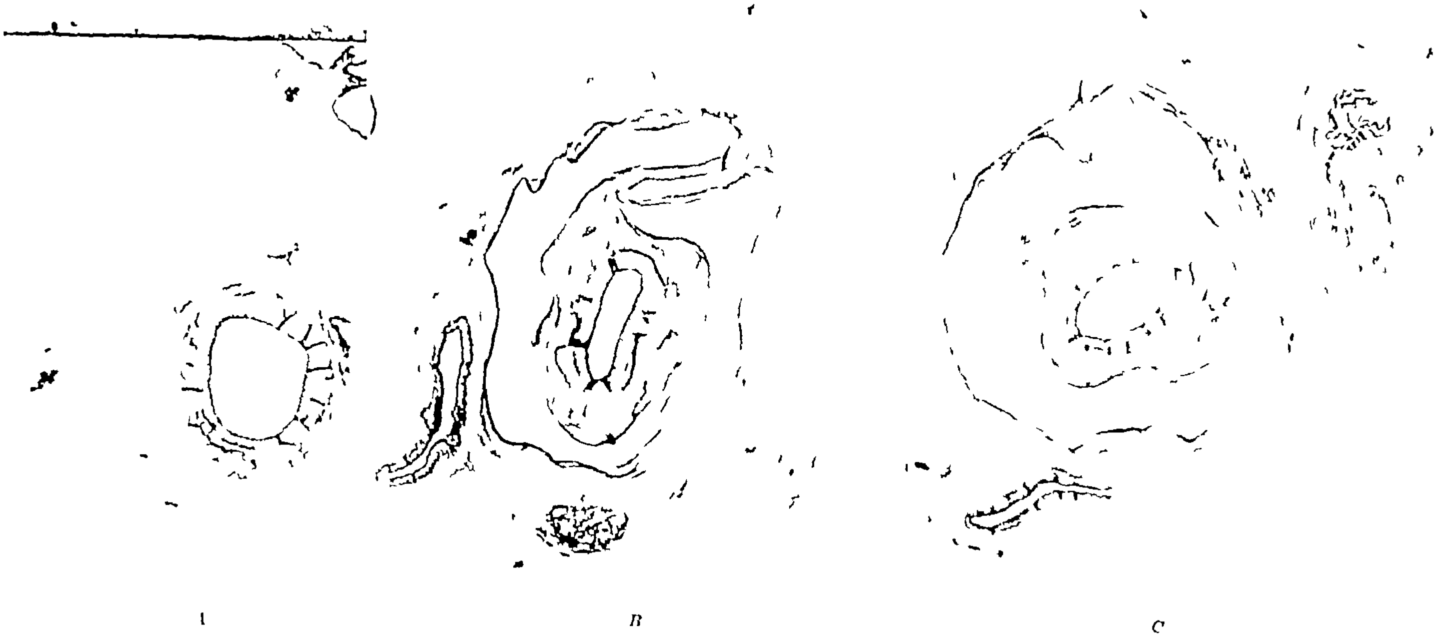

Fig. 1.—Three sections of abdominal aorta of dog sacrificed three months postoperatively. *A*, Control. *B*, wrapped with polyethylene impregnated with powdered asbestos. *C*, wrapped with polyethylene impregnated with powdered talc such as was formerly used in surgical gloves.

behind thoracic aneurysms This method appears to be useful in conjunction with wrapping but has definite limitations when used alone The presenting portion of the aneurysm, which has the thinnest wall and bulges out into the body cavity with little if any covering, offers no safe place for the insertion of a

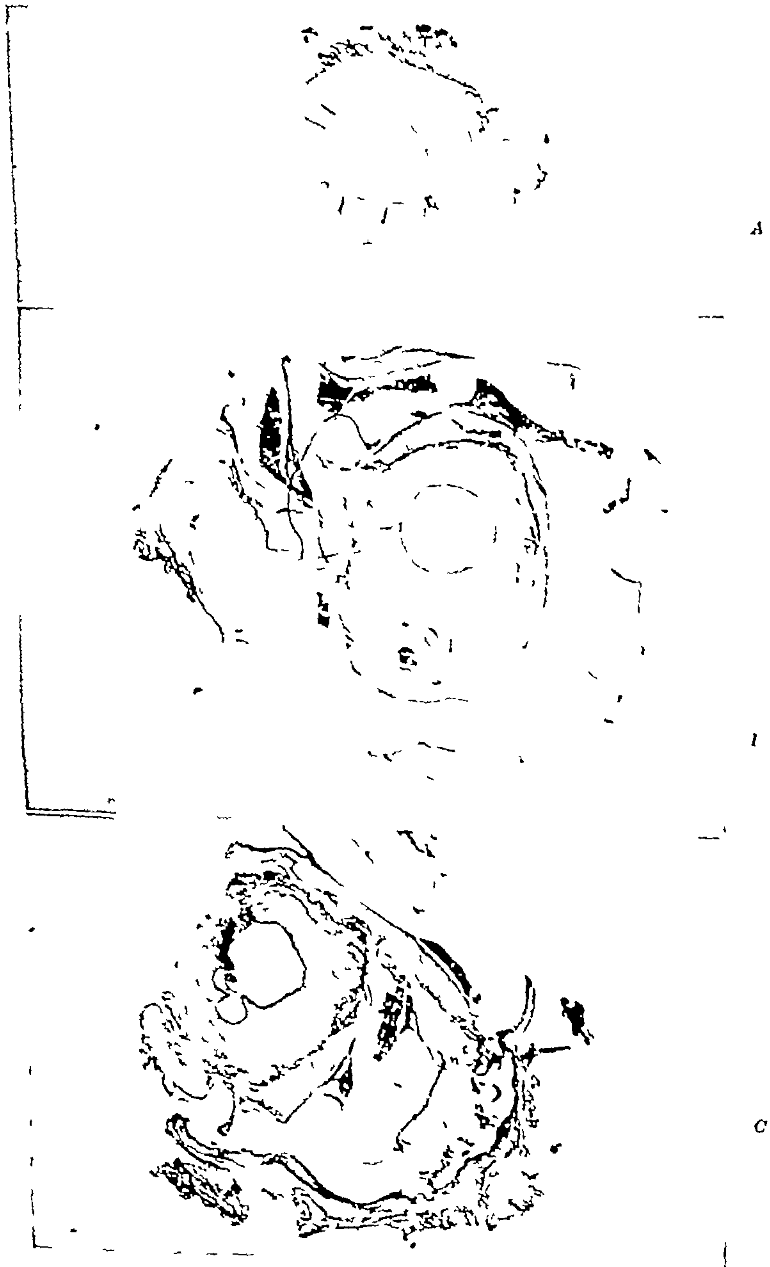

Fig 2—Three sections of abdominal aorta of dog sacrificed three months postoperatively A Control, B, wrapped with polyethylene covered on inside only with dicetyl phosphate C, Wrapped with polyethylene covered on both sides with dicetyl phosphate.

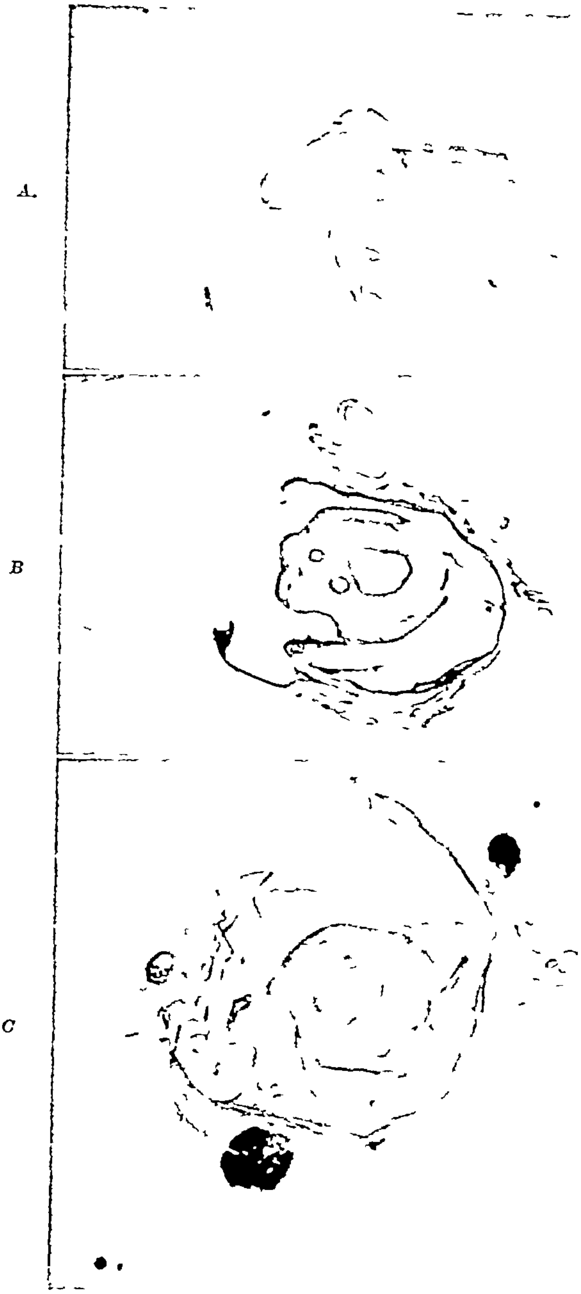

Fig. 3.—Three sections of abdominal aorta of dog sacrificed three months postoperatively. *A*, Control. *B*, wrapped with polyethylene covered on both sides with dicetyl prosphate sterilized by boiling ten minutes. *C*, Wrapped with polyethylene covered on both sides with dicetyl phosphate soaked for thirty minutes in 1:1000 aqueous Zephiran.

needle This method does not include freeing of the pleura or peritoneum along the sides of the vessel which represents the first step in preparation for wrapping and relieves a great deal of the preoperative pain The tendency for the oil to leak out into the pleural cavity has made me hesitate to use it around abdominal aneurysms where diffuse peritoneal adhesions would be quite undesirable

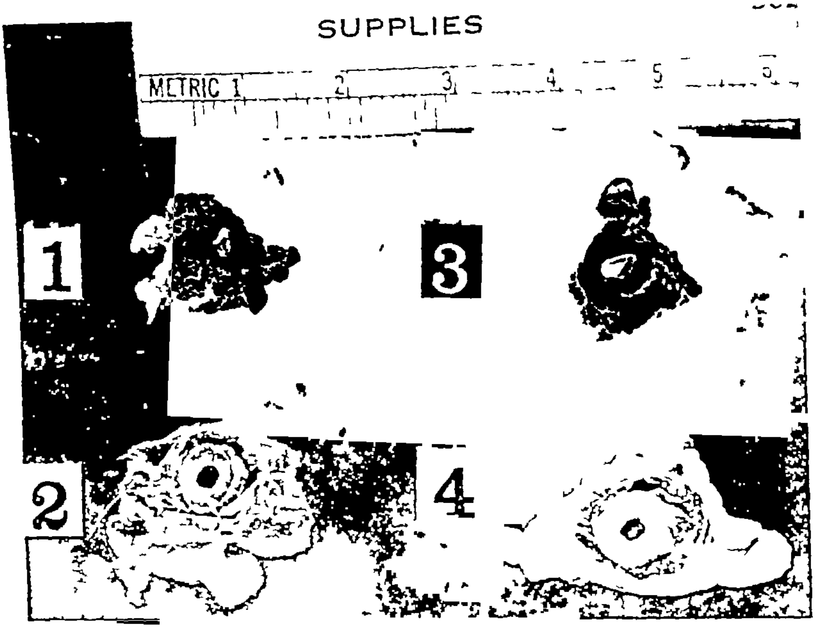

Fig 4 —Photographs of gross specimens of aorta of two dogs sacrificed three months postoperatively *1* and *3* Controls *2* wrapped with polyethylene covered on both sides with dicetyl phosphate sterilized by boiling ten minutes *4* Wrapped with polyethylene covered on both sides with dicetyl phosphate sterilized by soaking thirty minutes in 1 1000 aqueous Zephiran

Repeated animal experiments during the past five years have indicated that the greatest perivascular fibrosis is obtained by using polyethylene film which is heavily impregnated with dicetyl phosphate on both sides, as contrasted with the DuPont film which has only a small amount of phosphate on one side The application of nonreactive Cellophane around the outside of the polyethylene, as once suggested, tends to limit the fibrosis sufficiently to interfere with the purpose of the wrapping

The most effective preparation has been melting the dicetyl phosphate on the surface of the film This can be done by either one of two methods One method consists of spreading a thin layer of dry dicetyl phosphate powder evenly over the surface of a sheet of film and drawing this slowly over an electric plate until the powder has settled into the softened film The other method requires passing the film through molten dicetyl phosphate This latter method lends itself better to mass production techniques and permits a higher concentration of dicetyl phosphate but does not provide as firm an anchorage of the coating It must be remembered that 120° C is the melting point of polyethylene and

72° to 73° C is the melting point of dicetyl phosphate The electric plate should be just warm enough to melt the powder and soften the film without melting holes in the film

Other methods of coating the film have been recommended, such as immersing the film in benzene containing dicetyl phosphate Cold hydrocarbons cause polyethylene to swell and the dicetyl phosphate theoretically should become impregnated into the surface Experiments to date have not indicated a very satisfactory fixation of the phosphate to the film surface by this method The dicetyl phosphate has a tendency to rub off on handling the dry film

Laboratory and clinical experience with wrapping, patching, and wiring aneurysms has indicated that the application of polyethylene film containing dicetyl phosphate represents the most satisfactory method of treating aortic aneurysms[7] Admittedly, the film can rarely be placed completely around the aneurysm, it does not reduce the size of the aneurysm, it does not prevent the extension of the aneurysm with rupture in another area, and does not prevent rupture under the patch for a period of from four to six weeks postoperatively Wrapping is best suited to fusiform aneurysms of the descending aorta below the arch where large branches are less numerous Even with these limitations, wrapping affords a greater chance for relief of symptoms, prevention of rupture, and avoidance of fatal operative complications to a greater number of patients than any other method except resection

CONCLUSIONS

1 Polyethylene film wrapped around an aneurysm merely acts as a support for a chemical irritant which causes fibrosis and thickening

2 Dicetyl phosphate heavily applied to both surfaces of polyethylene film represents the most satisfactory irritant

3 Melting the dicetyl phosphate into the surface of the polyethylene provides the most permanent anchorage

4 Chemical sterilization of the film for twenty minutes in 1 1000 aqueous Zephiran solution has proved satisfactory without excessive loss of dicetyl phosphate

5 Heat sterilization disturbs both the polyethylene and the dicetyl phosphate

6 Prolonged soaking in any solution reduces the dicetyl phosphate concentration on the film

7 External reinforcement of aneurysms by wrapping represents the most effective method of treatment to aneurysms unsuitable for resection

Acknowledgment is hereby given for the valuable assistance provided by the University of Oregon Medical School, Washington University Medical School, The Oregon Heart Association, and the following physicians H Renault, W Ochs, J Hessel, T Gianelli, and J Kane W R Todd generously contributed his services in chemical analysis

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DISCUSSION

DR WILLIAM A HOPKINS, Atlanta—We, too, have been much interested in the use of Cellophane in thoracic and abdominal aneurysms At first, at the suggestion of Dr Poppe, we used Cellophane as prepared by the DuPont Company with such variable results that we were not entirely satisfied with this method However, I wish to report three later cases in which we used Cellophane We impregnated with a suspension of dicetyl phosphate that was painted on the Cellophane at the time of surgery This method was described by Dr Hufnagel This had some disadvantage because it cracks off very easily at the time of surgery and some of the dicetyl phosphate may therefore be deposited about the thoracic cavity We feel it is too soon at the present time to make any definite conclusions as to results There is one additional point I would like to bring up we have also wrapped aneurysms of the ascending aorta We feel that in our first cases there were considerable amounts of irritation within the pericardium, which produced arrhythmias that were very difficult to handle If the outer surface of the Cellophane is wrapped with nonreactive Cellophane this complication can be alleviated

DR GEORGE H HUMPHREYS, New York —At the Presbyterian Hospital in New York Dr Blakemore has been interested in treating aneurysms for a number of years, as I am sure you know His method has consisted primarily of wiring and electrocoagulation, but since the first reports of the use of reactive Cellophane this method has also been used. We have been disturbed not only by the inconsistencies in reaction, on the subject of which Dr Poppe has helped us a great deal with his presentation, but we have also been disturbed to learn from Dr Oppenheimer, at the Cancer Institute, that fibrosarcomas can be produced in rats with this agent. This fact, although rats are not human beings, seems to us a reason for hesitation There is a further theoretical consideration Treatment of aneurysms by this method, as Dr Poppe himself has mentioned, is very limited in certain respects It has perhaps more analogy to the treatment of hernia by injection and sclerosing agents A fibrotic reaction can resist an expanding tendency to a certain extent, but only to a limited extent Recently, Dr Deterling has tried another approach in the laboratory, using a nonreactive, nylon mesh, wrapping vessels, particularly grafted vessels, in order to prevent their late expansion into aneurysms This has proved very effective, at least in the experimental animal, and we are beginning its use in human beings

DR DENTON COOLEY, Houston —On the basis of our clinical experience with the polythene dicetyl phosphate film which was obtained from the DuPont de Nemours and Company, we agree with Dr Poppe that insufficient fibroplasia is produced by this untreated film to which additional irritant has not been added Recently, Dr DeBakey and I have reexplored two of our patients in whom an abdominal aortic aneurysm had previously been wrapped In both instances symptoms persisted and pain increased, and the aneurysm had definitely enlarged Although periods of thirteen and eight months, respectively, had elapsed, in neither patient was there evident exuberant fibrosis The polythene film had been prepared by soaking in 1 1000 aqueous zephiran solution for twenty to thirty minutes

(Slide) This is a color photograph showing the application of the film in December, 1951, to an abdominal aneurysm In July, 1951, a large sacciform aneurysm of the innominate artery was excised in this same patient and there has been no recurrence of this lesion

(Slide) *In this photograph the condition of the abdominal aneurysm at the second* laparotomy in January, 1953, can be seen The polythene film is encased in a paper thin membrane of fibrous tissue Indeed, the wall of the aneurysm itself appeared necrotic, as if the film of polythene had served to deprive the adventitial layers of vascular supply

(Slide) In this photomicrograph made from tissue forming the wall of the aneurysm and polythene film, one is impressed by the relatively slight amount of fibrosis produced Similar findings were present in the patient re explored eight months after the wrapping procedure

We are becoming increasingly skeptical of the efficacy of so called fibroplastic agents in the treatment of aneurysm Excision of the aneurysm with restoration of vascular continuity appears to be the procedure of choice, and we feel that it can be done in the majority of cases I disagree with Dr Poppe when he refers to wrapping and wiring of aneurysms as ideal treatment I consider such methods as compromises with ideal therapy, which should be surgical excision

DR POPPE (Closing) Dr Hopkins' comment about protecting adjacent vital structures around an aneurysm is well taken, but I prefer to use a layer of tissue, such as pleura, fat, or omentum, over the polyethylene film rather than adding a layer of non reacting Cellophane It is also necessary to distinguish polyethylene, which is a polymer of ethylene, from Cellophane which is a cellulose product A one sided reaction can be obtained with polyethylene by coating only one side of the film with dicetyl phosphate as was done with the DuPont film N V 7 14 Experimental work indicates the desirability of obtaining as much reaction as possible and this reaction is greatly reduced by eliminating or covering up the irritant on one side of the film

Dr Humphrey's suggestion about reinforcing aneurysms with nylon mesh around the outside is very interesting and should give a great deal of support if it can be used to completely encircle the aneurysm My experience would indicate that the majority of large aortic aneurysms are already eroding into some adjacent structure, such as the spine or sternum and cannot be completely encircled, thereby limiting the usefulness of this method

Dr Humphrey's report about dicetyl phosphate causing fibrosarcoma in mice is somewhat disturbing, but I doubt if any of these patients with aortic aneurysms will survive the fifteen to twenty years which would probably be required for the development of malignancy Some other irritant, such as asbestos or talc, could be substituted for the dicetyl phosphate

Dr Cooley's remarks about resection being the ideal treatment may apply to a limited number of aneurysms, but I still believe that wrapping is the treatment which is applicable to the greatest number of patients with the disease I am sure that at least 90 per cent of the aneurysms I see could never be resected Three of these aneurysms have ruptured spontaneously during the past three months within twenty four hours after being seen Better preparation of his polyethylene should improve his results with wrapping

I wish to thank the discussants for their very interesting and informative comments on this difficult problem of treating aneurysms of the aorta

ENZYMATIC DÉBRIDEMENT

Particular Reference to Trypsin and Desoxyribonuclease in the Control of Cough and Sputum Associated With Tuberculosis*

Seymour M. Farber, M.D. (by invitation), R. Daniel Gorman, M.D. (by invitation), David A. Wood, M.D. (by invitation), Orville F. Grimes, M.D. (by invitation), and Samuel L. Pharr, B.S. (by invitation)
San Francisco, Calif.

IN ANY chronic infection the collection of fibrin, degenerating cells, and the purulent exudate that soon appears considerably inhibits therapeutic measures. In the past, it has generally been necessary to clean such areas, when possible, by repeated surgical débridement. Except in superficial infections, débridement was frequently unsatisfactory and sometimes impossible. In many cases permanent disability and even death, have been directly attributable to this technical problem.

Recently the streptococcal enzymes, streptokinase and streptodornase and the pancreatic enzyme trypsin have been utilized for débridement. All these agents act to the same end the digestion of fibrin and necrotic products and none of them in therapeutic doses inhibits the growth of new granulation tissue. Thus, the risk that superficial trauma will delay healing is avoided.

Until recently interest in the use of these enzymes in the management of chest diseases had been limited to their usefulness in the treatment of pleural conditions (empyema and hemothorax) and infections of the chest wall sinuses. There is reason to hope however that one of these agents, or some related compound will eventually be useful in the management of a number of chronic chest diseases. One of them, trypsin has already been applied to the débridement of the bronchial tree. Because few reports on this type of application have appeared, our own experience with bronchial débridement will be discussed in some detail later.

STREPTOCOCCIC ENZYMATIC DEBRIDEMENT

In 1933, Tillett and his associates[1, 2] discovered that hemolytic streptococci, when cultured, excreted an enzyme, streptokinase, into the culture medium, which acted upon fibrin and markedly promoted the dissolution of human blood clots. In 1948 a second enzyme was demonstrated to be the product of the same bacteria.[3] This enzyme acted upon desoxyribonucleoprotein, which is largely responsible for the characteristic viscosity of purulent exudates. The first enzyme streptokinase was found to act indirectly, it converted plasminogen in human blood into plasmin which in turn dissolved insoluble fibrin into

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From the Cancer Research Institute and the Departments of Medicine and Surgery University of California School of Medicine and the San Francisco Department of Public Health (San Francisco Hospital).

Read at the Thirty-third Annual Meeting of The American Association for Thoracic Surgery San Francisco Calif., March 27 28 and 30 1953.

*The trypsin (Tryptar) and desoxyribonuclease used in this study were kindly furnished by the Armour Laboratories Chicago Ill.

soluble proteins The second enzyme, streptodornase, was found to be composed of a series of closely related enzymes which acted directly upon desoxyribonucleoprotein At the present time, these two enzymes are used in combination, four units of streptokinase to one of streptodornase

A number of studies on the application of this enzyme combination in various thoracic conditions have been published DeBakey[4] reported the combination particularly effective in the treatment of infected hemothorax He found that it produced marked thinning of the exudate and dissolution of loculations, and, in many instances, it obviated the need for thoracotomy Tillett, Sherry, and Read[5] emphasized the value of streptokinase and streptodornase in the treatment of tuberculous empyema They observed that the enzymes not only reduced the viscosity of the pleural fluid, but contributed directly to sterilization of the pleural space In general, streptokinase and streptodornase appear to be of proved service in the treatment of any condition in which an accumulation of viscous pleural fluid interferes with other types of therapy At the same time, it should be recognized that additional clinical work is required to establish the conditions under which optimum results can be anticipated.

TRYPSIN DÉBRIDEMENT

Trypsin is a pancreatic enzyme whose lytic action on mucus and fibrin has long been recognized It has only recently, however, become available in a sufficiently purified form to be used clinically Like the streptococcic enzymes, its obvious application in thoracic medicine lies in the treatment of pleural complications, and the range of its reported usefulness closely parallels that of streptokinase and streptodornase Roettig and his associates[6] emphasized in particular the effective sterilization of the pleural space obtained with trypsin, they concluded that the sterilization that followed treatment in fifteen of sixteen cases of empyema, including tuberculous empyema, was due in great part to the action of the enzyme These investigators attributed this antibacterial effect to the digestion of the pus and debris which apparently are necessary for growth of bacteria in pleural fluid Also, of course, the decrease in viscosity of such fluid effected by the enzyme permits more efficient antibacterial action by humoral defense mechanisms

BRONCHIAL DÉBRIDEMENT

The necessity for new measures for the management of pulmonary tuberculosis has become obvious Despite recent progress in surgical and antibiotic therapy of this disease, the control of symptoms, particularly the large quantities of sputum and excessive cough, remains a problem Since use of cough suppressants often leaves much to be desired, considerable effort has been expended in the past ten years to find a more satisfactory means of treatment These considerations are emphasized, we believe, by results of our own attempts to utilize trypsin to control the cough and heavy production of sputum associated with pulmonary tuberculosis

Logically, administration of trypsin by aerosol inhalation should aid in the control of these symptoms Limber and his co-workers,[7] in the first pub lished study of the effect of this enzyme on abnormal bronchial secretions concluded that trypsin was of value in the treatment of a number of pulmonary conditions Our early trials with trypsin alone however demonstrated that the action of trypsin seems to be confined to mucus fibrin and noncellular material. Since the viscosity of purulent sputum is largely due to its high content of desoxyribonucleic acid it was felt that trypsin might profitably be supplemented with desoxyribonuclease a pancreatic enzyme which had been demonstrated specifically to depolymerize desoxyribonucleic acid in in vitro studies[5]

Selection of Patients—The twenty-four patients included in this study had excessive cough and consistently raised large quantities of sputum The majority had far-advanced pulmonary tuberculosis and had undergone collapse procedures, as well as treatment with antibiotic and chemotherapeutic agents A few patients however, were given trypsin shortly after hospitalization and before any specific therapy was instituted Four of the twenty-four patients had associated bronchiectasis, suspected or proved, four had tracheobronchial tuberculosis and four had marked emphysema and bronchial asthma One patient had a coexistent pulmonary neoplasm proved by cytologic studies of the sputum

Technique—Trypsin was administered by aerosol inhalation The most satisfactory method was by means of a Vaponefrin nebulizer which consisted of the nebulizer itself a rubber bag containing hot water to humidify the aerosol mixture and a nosepiece By this approach, the nose acts as a baffle, removing the larger drops of moisture which are usually the chief source of bronchial irritation No irritation of the larynx or throat was noted with this method of administration although such irritation had been a serious problem at the beginning of the study when an ordinary mouth nebulizer was used Nasal irritation was minimized by the application of petroleum jelly prior to inhalation and a thorough rinsing of the nose and throat immediately afterward

Materials—Dosage and length of administration varied At the beginning of the study each patient received 1,000 Armour units of trypsin daily, but it was rapidly demonstrated that doses of 100,000 units could be tolerated later, the dose was increased to as much as 100 000 to 150 000 units daily The course of treatment ranged from three to thirty-two days with an average of ten days, several patients received more than one course of therapy

The first eleven patients in the series were given one course of trypsin alone Sixteen patients were given desoxyribonuclease in addition to trypsin in doses ranging from 2 mg daily for four days to 5 mg daily for eleven days One patient received 5 mg of desoxyribonuclease alone each day for four days without apparent benefit

Sorensen s buffered phosphate solution in volumes not exceeding 2 5 c c per inhalation was the diluent in most instances On several occasions physiologic saline solution was substituted for the phosphate buffer solution, but it did not reduce the incidence of local reactions

Method of Evaluation—The primary interest was in the effect of these enzymes on cough and sputum production Patients were carefully observed during and after each course of inhalation, and each day sputum was collected, measured, and a record kept of volume and gross appearance The usual standard clinical tests were performed on all patients

In addition, the possible effect of trypsin and desoxyribonuclease on pulmonary function was carefully evaluated in six patients The Warring method[9] was used, since our previous experience with 450 patients had convinced us that it provides a helpful index of variations of pulmonary function None of the six patients showed a significant change in WV/M.B C ratio after administration of these enzymes Cytologic examination of the sputum was performed in sixteen patients Control sputum specimens were obtained before treatment to establish a typical "cellular picture" for each patient, and specimens were collected at intervals after treatment was begun for comparison and evaluation[10-14]

Results—The most favorable effects on cough and production of sputum were obtained by a combination of trypsin and desoxyribonuclease Only three of the eleven patients who received a course of trypsin alone were noted to have a decrease in cough whereas in the remaining eight patients, cough appeared to increase in severity On the other hand, nine of the sixteen patients who received combined therapy showed a significant reduction in cough, and in three of these the response was marked

Sputum was decreased in quantity by trypsin alone in four cases and by trypsin and desoxyribonuclease in six others In the majority of patients, however the amount of sputum raised was increased by therapy Eleven of the sixteen patients who received the enzymes in combination believed that the raising of the sputum was noticeably easier following treatment

Use of the combined enzymes resulted in a grossly evident decrease in both the viscosity and the purulence of sputum in eight instances, and in a decrease in viscosity alone in an additional two In no instance, however, did trypsin alone effect a striking change in the gross appearance of the sputum

Toxicity—The frequency of mild irritative reactions following the administration of these enzymes has been noted We were more impressed, however, by the number of moderate to severe reactions of various kinds which occurred following administration of both trypsin alone and of trypsin and desoxyribonuclease In the majority of cases the reactions obviously resulted from the local irritating effect of trypsin, and perhaps also of desoxyribonuclease They consisted of hoarseness and aphonia, severe cough and hemoptysis which occurred in seventeen (71 per cent) of the patients Administration of the enzymes by nasal inhalation reduced the severity of the reactions and the incidence of local irritation but twelve of twenty patients so treated still demonstrated appreciable side effects In nine instances these reactions were so severe that the patients refused further inhalations

The occurrence of generalized toxic reactions was of greater significance The most common reactions were severe dyspnea and wheezing which usually immediately followed inhalation, chills and fever which appeared some four hours later and a generalized rash The incidence of these reactions was not affected by the method of administration

Three patients developed chills and fever following aerosol inhalations. One patient's temperature rose to 104° F on five occasions after which treatment was discontinued. Another patient developed a morbilliform rash after completion of a series of inhalations. This rash was most severe on the trunk and decreased toward the extremities. It disappeared gradually over a period of two weeks.

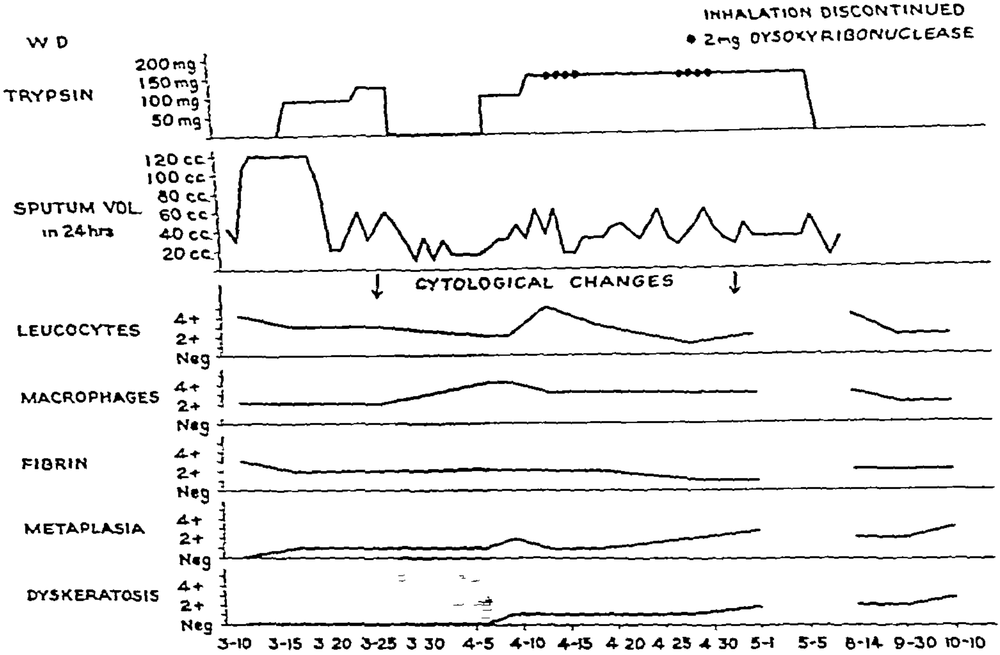


Fig 1—Cytologic changes in a patient (W D) receiving trypsin and desoxyribonuclease by inhalation.

Cytologic Findings—Cytologic studies failed to show any evidence of destruction or lysis of formed elements in the sputum or any alteration in fibrinous elements. Enzyme therapy did however affect the quantity of macrophages and inflammatory cells in the sputum (Fig 1). This response followed a definite pattern: the sputum showed a sharp increase in the number of macrophages and inflammatory cells during the first two hours after inhalation followed by an abrupt decline toward preinhalation levels. The number of cells again increased gradually for a period of days then dropped slowly back to preinhalation levels. We cannot account for this specific pattern, although the increase in inflammatory cells and macrophages would seem to be an irritative response.

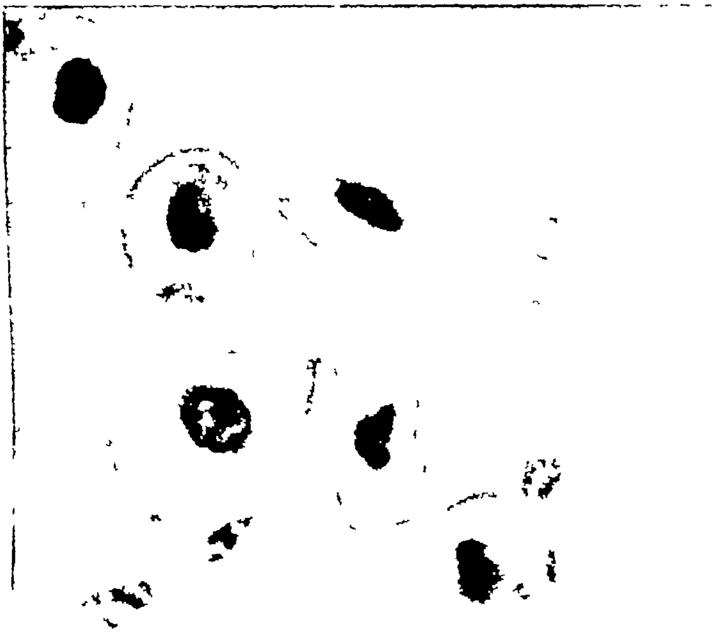
In twelve of sixteen patients cytologic examination of the sputum showed changes in exfoliated epithelial cells which were consistent with bronchial metaplasia and dyskeratosis (Figs. 2 to 4). These alterations consisted of enlargement of nuclei with vacuolization and increased keratinization of the cytoplasm. The abnormal cells appeared soon after trypsin inhalation was begun and have persisted to the present time, despite discontinuance of therapy. We are unable to evaluate fully the significance of these observations, but additional studies are indicated.

Discussion.—Although in a majority of the patients in this series, some decrease in severity of cough and in viscosity of sputum followed enzyme therapy, our own results were considerably less impressive than those obtained by Limber and his associates.[2] Further, it was our impression that desoxyribonuclease was an essential factor in the improvement noted. Our most consistent finding was decrease in sputum viscosity. In most instances, however, there was an actual increase in the production of sputum, whereas Limber found a decrease. It must be remembered, of course, that the Limber cases included a variety of pulmonary conditions; our patients had pulmonary tuberculosis as the primary disease process in every instance. In addition, antihistamines were used sparingly in our patients.

Fig. 2.—Typical bronchial epithelial cells (X776).

The most striking difference between our results and those previously reported was the frequency of moderate to severe reactions to enzyme administration in our patients. Although considerable local irritation was eliminated by the use of a Vaponefrin nebulizer, nevertheless twelve of the twenty-four patients given enzymes by nasal inhalation were found to have side effects of one kind or another.

Fig 3



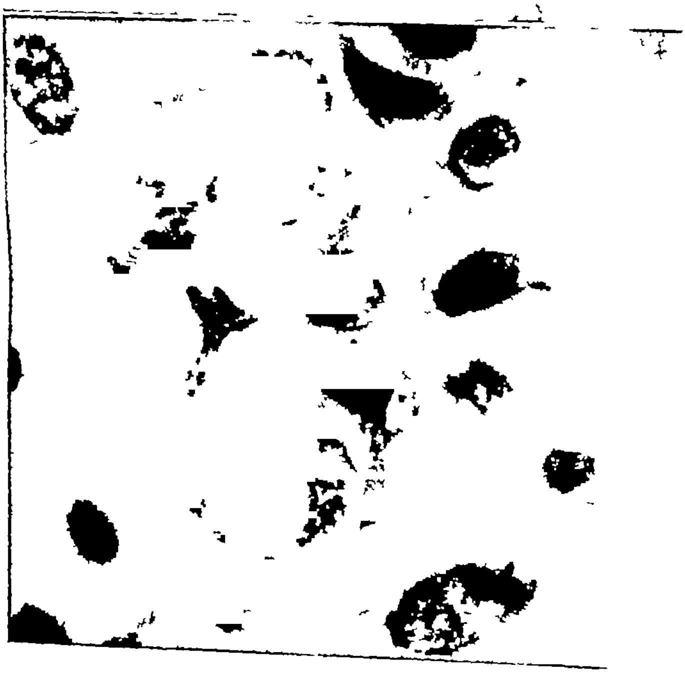


Fig 4

Fig 3—Typical metaplastic cells (×776)

Fig 4—Atypical cells observed in sputum of W D following inhalation of trypsin and desoxyribonuclease (×776)

The most serious of these effects was the development of a typically asthmatic episode of wheezing and dyspnea. Once a patient experienced such an attack, additional therapy generally resulted in increasingly severe reactions. Continued treatment was possible in only one of eight patients in whom this reaction developed. Pyribenzamine had no effect upon this tendency in any of the three patients receiving it. The episodes of chills and fever that developed in three of twenty-four patients were equally serious. In two cases, these episodes were isolated instances, in the third patient, they were invariable.

The asthmatic attacks obviously represented a specific sensitivity. It is likely that the chills and fever were a different manifestation of the same phenomenon, although they may have resulted from absorption of products of enzymatic digestion. Such absorption would have much the same effect as the intravenous injection of partially digested protein products. It is perhaps worth noting that the repeated episodes of chills and fever occurred in one of the few patients in whom the therapy was markedly effective in reducing cough and thinning sputum.

Last, four patients who had no previous history of hemoptysis noted blood streaking of the sputum ten days or more after inhalation was begun. Although of little importance in itself, since the amount of blood raised was small, this symptom gave further evidence of the toxicity of these compounds. Reiser and his co-workers[16] noted a similar phenomenon in their treatment of empyema cavities with trypsin, hemorrhagic pleural fluid frequently appeared from four to seventeen days after instillation was begun.

On the basis of these studies, we have concluded that trypsin and desoxyribonuclease should not be recommended for routine use in the treatment of tuberculous patients with productive cough. A few of our patients seemed to show a distinct long-term improvement and the majority benefited temporarily, but it was felt that the toxicity of these compounds outweighed their beneficial effects.

These objections are obviously not insurmountable. Bowman[17] reported that iodinated trypsin does not have the marked hypotensive effect on dogs that trypsin has, other modifications would seem to be possible. Of great interest is the recent announcement of a preparation of trypsin of such low toxicity that it may be administered intravenously.[18] When such a product becomes generally available it may well remove present objections to the use of the enzyme. It will also be necessary to evaluate the cytologic findings herein reported.

SUMMARY AND CONCLUSION

Two enzyme products, trypsin and a combination of streptokinase and streptodornase, have recently been applied to the problem of debridement of various kinds of chronically infected areas. In the field of chest disease they have been chiefly of value for their possible contribution to the management of empyemas and postoperative or traumatic hemothorax.

It is emphasized that the addition of enzymes to this kind of therapy is still in the developmental stage and it should be approached with caution. This is confirmed by our own use of trypsin for bronchial debridement. Twenty-four patients with pulmonary tuberculosis who had excessive cough and who were raising moderate to large amounts of sputum were given trypsin alone or in combination with desoxyribonuclease by aerosol inhalation Trypsin alone was of little effect but in combination with desoxyribonuclease, it reduced cough and viscosity of sputum in a majority of cases Results were not marked, however except in three patients who showed a substantial decrease in cough Almost three-fourths of the patients in the series had significant reactions Sensitivity reactions in the form of chills and fever or asthmatic attacks were encountered Cytologic studies of the sputum of sixteen patients revealed increased metaplasia in the cellular components in twelve of them

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DISCUSSION

DR C THOMAS READ Phoenix.—When I came to this meeting I said to someone that I was not going to mention anything about varidase or streptokinase or streptodornase However, after hearing this rather exciting paper and the excellent work demonstrated by Dr Farber I arise mainly to ask him if a comparable control study was run at the same time with varidase Trypsin was available to Dr Sherry in the early part of our studies, and we too found quite a decided reaction when the agent was instilled into the bronchus mainly by aersol therapy

Recently Winthrop Stearns, Inc has manufactured a product known as Alevaire, of which they sent me a quantity for clinical trial before it was released to the profession It formed a good vehicle for varidase if a patient had indicated symptoms for such aerosol therapy Antibiotic agents can be used with Alevaire and also varidase and aerosol therapy thereby given, which will reduce the purulent character of sputum I mention the purulent character because it was shown that purulent exudates contain about 30 to 70 per cent of nucleoprotein and these are the elements which are affected by varidase If the sputum or exudates are mucinous in character, varidase is not effective That seems to be the advantage of trypsin or the pancreatic enzymes, lacking in varidase

I would like to ask Dr Farber also if the *desoxyribonucleoprotein element,* its amount and so on, was demonstrated in the exudates they were studying

DR DUANE CARR, Memphis —Dr Read has already mentioned a product with which we are *now* working, *Alevaire, as an adjunct to the treatment for the reduction of sputum,* particularly in the preparation of patients for surgery This product is thoroughly applicable to the tuberculous patient as well as the one with suppuration or a very purulent bronchiectasis

Its one possible theoretical disadvantage, which remains to be determined, is the fact that it acts as a wetting agent, reducing surface tension, which is advantageous in improving the ability of the patient to raise his sputum, but may prove a disadvantage because of the drying effect within the lung itself

We all know that the contractility of the lung is in part due to surface tension of the moisture lining the alveolar air spaces We also know that in the patient with emphysema one of his principal difficulties is the lack of contractility of his lung, so that Alevaire can not yet be used with complete confidence in the emphysematous patient. Symptomatically, it is extremely effective and can be used as a vehicle for the appropriate antibiotics if the use of aerosol therapy is desired Its effect is particularly striking in the bilateral purulent bronchiectatic patients who, in some instances, may be raising as much as one pint of sputum per day When the patient is placed upon a routine of aerosol inhalations of appropriate antibiotics and Alevaire three or four times a day, combining it with the usual postural drainage routine, the regimen reduces sputum from one pint to as little as one ounce or one and one half ounces, almost totally lacking in purulent elements

We are very interested in the work of Dr Read, Dr Sherry, and Dr Christensen in the use of streptokinase and streptodornase and have used it extensively for other purposes, particularly in the pleural cavity, but to date we are enjoying a very satisfactory result from the use of Alevaire with antibiotics and the postural drainage regimen

DR FARBER (Closing) —I very much appreciated the comments of Dr Read In the April, 1951, issue of the JOURNAL of this Association, there is an excellent paper, with Dr Read as one of the co authors, on the use of streptokinase and streptodornase in the treatment of empyema The pioneer work in the entire field of enzyme therapy as applied to the thoracic cavity has originated in *Dr Tillett's group*

Dr Read mentioned the use of Alevaire, and Dr Carr has followed with very important suggestions as to the usefulness of this particular preparation We also have received some, but our experience is most limited, and hence I was happy to hear these comments As yet, Dr Read, we have not carried out cytologic studies with streptokinase and streptodornase

This work is in its early stages and should be repeated and carried forward in other cytologic laboratories

AN EXPERIMENTAL STUDY OF THE EFFECT OF PARASYMPATHETIC DENERVATION OF THE LUNG ON PULMONARY ARTERY PRESSURE

VICTOR H KAUNITZ, M D (BY INVITATION), AND MURRAY N ANDERSEN, M D
(BY INVITATION)
BUFFALO, N Y

BECAUSE of the dearth of knowledge of the mechanisms regulating the lesser circulation, it was thought useful to study changes in the pulmonary vascular bed following complete parasympathetic denervation of the lung in the experimental animal This study was facilitated by the availability of a measurement of complete parasympathetic denervation of a lung

This test consisted of determining the presence or absence of the Hering-Breuer reflex unilaterally during bronchospirometry Juvanelle,[1] working in our laboratory on bronchospirometry in dogs found that after occluding the airflow from one lung at the end of expiration, the Hering-Breuer reflex was not activated The animal continued to breathe normally without a period of apnea (Fig 1) If the airflow was occluded at the end of inspiration, or if the lung was forcibly inflated, which was necessary occasionally when ventilatory volume was depressed by deep anesthesia, stretch receptors in the lung were continually activated. Inspiration was inhibited and apnea occurred (Fig 1) The Hering-Breuer reflex, described originally in 1868 and measured in the isolated vagus fiber by Adrian[2] in 1933, was in operation When enough carbon dioxide accumulated, or when the arterial oxygen level fell sufficiently, the respiratory center was stimulated, escaped from the inhibitory impulses, and respiration was resumed.

After vagus section in the neck, or division of all vagus branches to the lung, when that lung was inflated, there were no longer inspiratory-inhibiting impulses reaching the respiratory center Normal respiratory rhythm continued without apnea (Fig 1) The homolateral Hering-Breuer reflex had been abolished This reflex was known to be transmitted via vagus afferent fibers from the lungs It is assumed that vagus efferent impulses travel along the same pathways[3, 4] Absence of the Hering-Breuer reflex would therefore indicate complete parasympathetic denervation of the lung

METHOD

Ten healthy mongrel dogs were studied by means of the described ventilatory test, and by cardiac catheterization preoperatively and after parasympathetic denervation of both lungs Under intravenous Nembutal anesthesia, a specially constructed bronchospirometry tube was passed into the trachea with the animal in a supine position (Fig 2) The tube was fastened in place and

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From the Surgical Research Laboratory of the E. J Meyer Memorial Hospital and the University of Buffalo Medical School

Read at the Thirty-third Annual Meeting of The American Association for Thoracic Surgery San Francisco Calif March 27 28 and 30 1953 connected to a bronchospirometry apparatus which recorded a simultaneous tracing of the ventilation of both lungs This apparatus was similar to that used in the human cardiopulmonary laboratory, except that the spirometer bells had a smaller volume Presence of the Hering-Breuer reflex bilaterally was confirmed

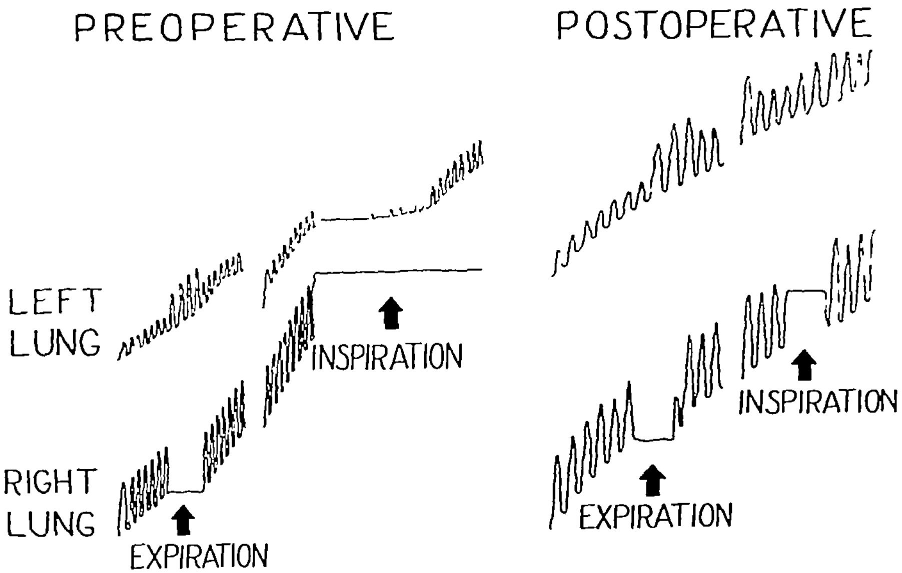

Fig 1—Effect of parasympathectomy on Hering Breuer reflex.

Cardiac catheterization was then performed during the same anesthesia The pulmonary artery was entered in all animals, and pressure recording was made during withdrawal of the catheter from a parenchymal branch of the pulmonary artery into the main artery and into the right ventricle Pulmonary artery pressure was calculated in all cases from that part of the tracing just before the right ventricular pressure curve (Fig 3)

Left thoracotomy was then done under intravenous Nembutal anesthesia Alternating positive pressure controlled respirations were maintained by oxygen flowing through a Burns valve connected to an endotracheal tube The vagus trunk was carefully isolated, and all branches to the lung were dissected free (Fig 4, *B*) From ten to thirteen branches were found and divided Thoracic cardiac nerves were preserved The lung was then reinflated by manually squeezing a small rebreathing bag attached to the sidearm of the endotracheal tube In this way all atelectatic areas of the lung were reaerated and complete re-expansion achieved

After an interval of approximately four weeks, a right thoracotomy was done Six to ten vagal branches to the lung were found on this side and divided (Fig 4 *A*) In the last four dogs femoral arterial pressures were measured during the second operation to determine if this parasympathetic denervation had any effect on cardiac output, as reflected in systemic pressure After another four-week interval each animal was again anesthetized, and the ventilation test and cardiac catheterization repeated

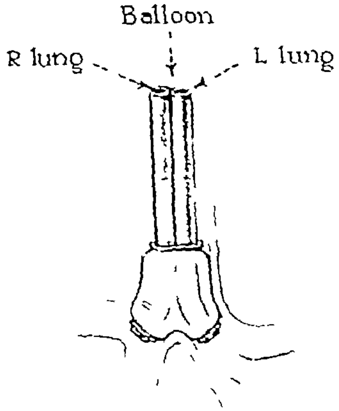

Fig 2 —Positioning of the bronchospirometry tube in the trachea.

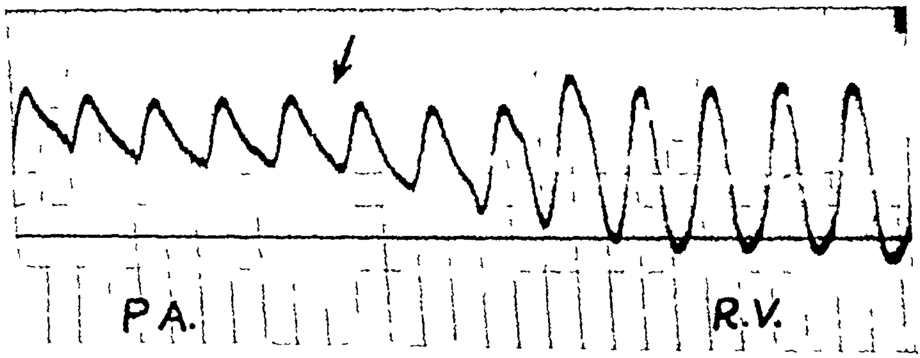

Fig 3 —Cardiac catheterization pressure tracing

RESULTS

In all dogs, division of the vagal branches to each lung resulted in bilateral absence of the Hering-Breuer reflex It is assumed, then, that in all animals a complete pulmonary parasympathetic denervation was produced Fluoroscopic and x ray examination at the time of the final cardiac catheterization confirmed complete re expansion and aeration of both lungs In nine of the ten dogs studied, there was an appreciable fall in pulmonary artery pressure following pulmonary parasympathectomy (Fig 5) The drop in pressure varied from 31 per cent to 71 per cent, with an average decrease of 46 5 per cent Pressures in the right ventricle showed a corresponding change (Table I) Cardiac output, as reflected in systemic blood pressure, showed no change immediately following the denervation

DISCUSSION

In the literature there are many confusing statements concerning the regulation of the pulmonary circulation by nervous mechanisms. Wiggers[5] states that vasomotor nerves are present to the lesser circulation, with vasoconstrictor impulses passing over the sympathetic pathways. He believes that evidence as to the course or even the existence of vasodilator fibers remains less certain, and rather confusing. Cournand[6] states that there is little conclusive evidence for vasomotor control of the pulmonary circulation in normal man. Drinker thinks that there is no reason as yet to believe that the pulmonary capillaries behave like those in the systemic circulation. He doubts the same type of parasympathetic and sympathetic control, which would be acting on the bronchial arteries, since they are systemic in origin.

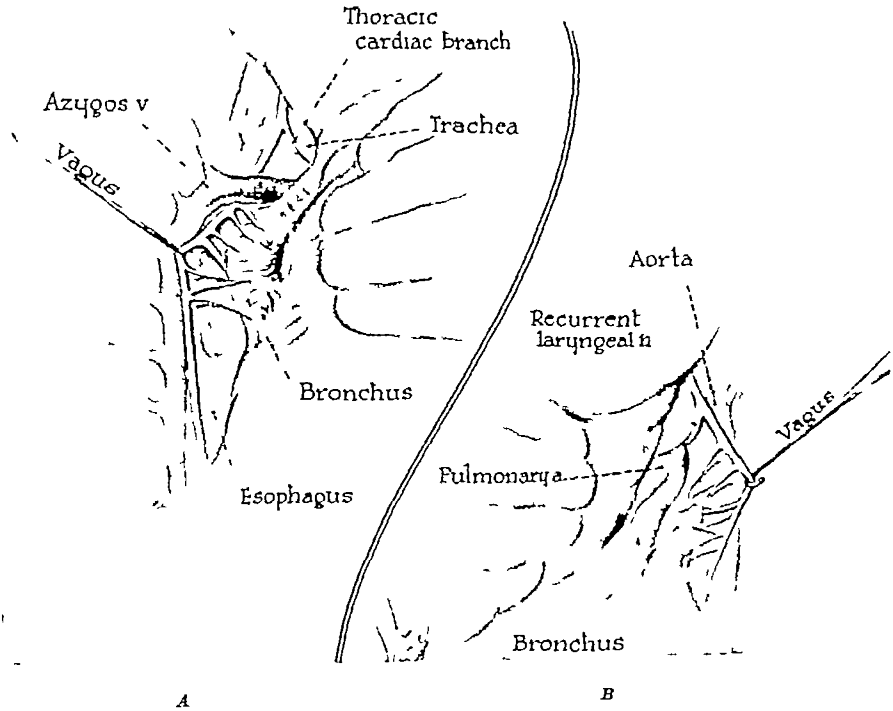

Fig 4.—Vagus branches to right (*A*) and left (*B*) lungs.

Zimmerman[8] believes that there is a direct neurogenic control of the pulmonary circulation. He found that in man, adrenalin injection, which he assumed to mediate sympathetic vasoconstriction, resulted in an increased pulmonary artery pressure. Aminophylline resulted in a fall in pulmonary artery pressure, assumed to be due to parasympathetic stimulation and resultant pulmonary vascular dilatation. These drugs have manifold actions, however, including their effect on cardiac output. It is therefore perhaps unwarranted to assume that any effect on pulmonary artery pressure resulting from their use is due solely to their action on the pulmonary vascular tree.

TABLE I PULMONARY ARTERIAL AND RIGHT VENTRICULAR PRESSURES (MM HG) BEFORE AND AFTER BILATERAL PULMONARY PARASYMPATHETIC DENERVATION

DOG NO	PULMONARY ARTERY PREOP	PULMONARY ARTERY P O	PULMONARY ARTERY % SYSTOLIC CHANGE	RIGHT VENTRICLE PREOP	RIGHT VENTRICLE P O	RIGHT VENTRICLE % SYSTOLIC CHANGE
B 1	21/9	37/21	+43	20/2	31/0	+35.5
2	40/23	20/7.5	-50	43/9	23/0	-46.5
3	25/2.5	16/8	-36	25/0	16/0	-36
4	34/18	10/6	-71	35/0	10/0	-71
5	18/5	12/4	-33	25/-3	11.5/0	-54
6	21/5	14.5/6	-31	24/-8	14/0	-42
7	16/11	8.5/3.5	-47	18/0	9/0	-50
8	23/8	13/5	-43.5	28/0	12/0	-57
9	30/5	19/11	-37	27/-4	21/0	-22
10	20/5	6/3	-70	23/-6	6/0	-74
			av fall = 46.5%			av fall = 50.3%

Dresdale and his associates[9] in a study of patients with so-called primary pulmonary hypertension find that Priscoline produces a transient lowering of the pulmonary artery pressure. Since this agent is sympatholytic they conclude that pulmonary hypertension is perhaps related to isolated sympathetic overactivity and broach the question of thoracic sympathectomy in its treatment. The same objection may be raised to this conclusion since Priscoline is a drug acting throughout the body and not only on the pulmonary vessels. The results of our study, moreover, if confirmed by further repeated observations would indicate that more attention should be directed toward the parasympathetic innervation.

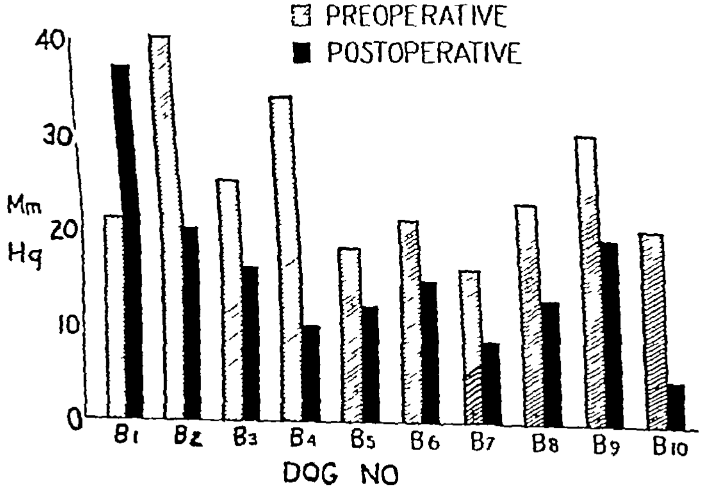

Fig 5.—Effect of parasympathetic denervation of the lung on pulmonary artery pressure.

Rodbard[10] advances the theory that the bronchiolar muscular tone is of prime importance in regulating the pulmonary circulation, because of its effect on intra alveolar pressure. Intra-alveolar pressure falls when the bronchioles dilate during inspiration and rises when the bronchioles constrict during expiration. Changes in intra alveolar pressure are reflected in an increased pulmonary artery pressure during expiration, and a decreased pressure during inspiration Adrenergic influences dilate the bronchioles, which should result in a decreased pulmonary artery pressure Vagotonic influences cause bronchiolar constriction, and consequently should increase pulmonary artery pressure Vagus denervation of the lung would therefore be expected to allow an unopposed bronchiolar dilating action of normal sympathetic tone, resulting in a lowering of pulmonary artery pressure We have demonstrated a decrease in pulmonary artery pressure following pulmonary parasympathetic denervation Whether the mechanism of this effect, however, is directly on the vessels or indirectly on the bronchioles is not clear

Blades and his co workers[11] mentioned a study of the pulmonary artery pressure in dogs before and after their operation of bilateral pulmonary plexus resection A decrease in pressure in one dog was cited after the operation This procedure was intended to produce both a parasympathetic and sympathetic denervation of the lung, however Therefore the part played by either parasympathetic or sympathetic activity in controlling the pulmonary vascular bed is difficult to determine in their experiment

Parasympathetic denervation of the lung has been recommended in the past for various types of pulmonary pathology Klassen and associates[12] [13] have utilized it for palliation in inoperable carcinoma of the lung and as treatment for intractable asthma They state that each side of the bronchial tree receives nerve fibers from the contralateral vagus and sympathetic nerves This is not borne out by our findings, for in all dogs studied, homolateral absence of Hering-Breuer reflex was demonstrated following unilateral parasympathetic denervation This would indicate that vagus innervation of the lung is unilateral The work of Larsell and Burget[14] substantiates this, for they demonstrated absence of cough on stimulation of intrapulmonary bronchi after ipsilateral section of the vagus nerve

Abbott with his co workers[15] tested complete pulmonary autonomic denervation, either alone or as an adjunctive procedure, in a variety of conditions, such as asthma, pulmonary emphysema, and bronchiectasis Blades and his associates[11] reported on complete autonomic pulmonary denervation in the treatment of intractable asthma In all these discussions, a complete parasympathetic denervation of the lung was assumed, but not proved Judging from the magnitude of the dissections described, the denervations were complete It would be valuable, however, to have objective proof of this, by testing for the presence or absence of the Hering-Breuer reflex postoperatively with the bronchospirometric technique described previously Then, too, perhaps so extensive a dissection is not necessary to produce a total parasympathetic denervation The absence of the Hering-Breuer reflex should enable the surgeon to determine the minimal division of nerve fibers needed to produce a total denervation effect

CONCLUSIONS

In the dog, complete parasympathetic denervation of both lungs was accomplished by dividing only the vagus branches to each lung Completeness of the denervation was proved by demonstrating the bilateral absence of the Hering Breuer reflex postoperatively A decrease in pulmonary artery pressure was observed as a result of this pulmonary parasympathetic denervation This would indicate that the parasympathetic innervation of the lung has a significant role in the regulation of blood pressure in the lesser circulation Whether this is a direct or indirect effect is not known

SUMMARY

1 A test for determining completeness of parasympathetic pulmonary denervation is described This consists of determining the presence or absence of the Hering-Breuer reflex unilaterally during bronchospirometry

2 Following pulmonary parasympathectomy pulmonary artery pressure fell in nine of ten dogs studied, with an average decrease of 46 5 per cent

3 The use of the test for complete parasympathetic denervation of the lung is discussed with reference to operative procedures designed to accomplish this result clinically

The technical assistance of Miss Mary Marcy and Mr William Kammerer is gratefully acknowledged.

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DISCUSSION

DR EDWARD J BEATTIE, JR, Chicago —I have enjoyed Dr Kaunitz's discussion of this problem very much, and I was interested in his further work on it Dr Blades and I struggled with this same problem for several years and unfortunately even after that time could not come to a final definite conclusion There is one question I would like to ask Dr Kaunitz. Did he or is he planning to run any bilateral thoracotomy control experiments to contrast with this series? In dogs we found that the bilateral operation in itself had certain adverse effects

One thing we did in trying to study the problem was to try to estimate the response of the lesser circulation to emboli after the lesser circulation had been denervated Of course we were trying to produce complete denervation, getting both the parasympathetic and the sympathetic I found that although in some animals there seemed to be some drop in pulmonary artery resting pressure after denervation, yet if we used embolization some months after denervation, the degree of hypertension produced in the experimental animals with the pulmonary artery denervated was just about as high as in the animals that had not been denervated, the bilateral thoracotomy controls Pulmonary pressure after giving emboli could rise over 100 mm of mercury systolic pressure in the pulmonary artery

Another point that is worth emphasizing is that attempts to study the dynamics of the lesser circulation with drugs is very difficult, because it is difficult to know whether the drug is producing its effect on the left side of the circulation or the right side of the circulation I know of no way that I could tell what the effect of the drug was, because of fall in pressure due to relaxation of the peripheral arterioles, change in left ventricular output, and so forth

Dr Blades and I hoped we were going to get the answer to this problem in some of our human patients in doing the asthma operation After our struggles in the laboratory it seemed to me that we could get an answer to some of the problems by measuring the pulmonary artery pressures with a cardiac catheter in human patients in whom we were later going to denervate *the* lungs for asthma operations Unfortunately, we *started this* project just about the time we stopped doing asthma operations, cortisone and ACTH came along, and our cardiac consultants had difficulty in getting the pressures, so I cannot give you the data But I think that may be the way to get the answer if we start doing asthma operations again I think that some of the problems are by no means solved, however

DR J KARL POPPE, Portland—This paper has been extremely interesting to me and I would like to report one case of Ayerza's disease or primary pulmonary hypertension in which I did a plexectomy This patient, a 33 year old man, came to me after having spent approximately nine months of almost complete hospitalization, being discharged for only periods of six or eight hours at a time before he returned in search of more oxygen to relieve precordial pain and dyspnea of which he complained. Based on Blades' report that the removal of the sympathetic and parasympathetic nerves on the left side would reduce the pulmonary artery pressure in dogs, that procedure was done according to the method described by Blades, of resecting all the nerve fibers around the bronchus, the pulmonary artery, and the two pulmonary veins

This particular patient had that done three years ago Before operation he had a pulmonary pressure of about three times normal level Since that time he has had three subsequent cardiac catheterizations, once each year, and the pressure has been normal on each occasion He was expected to require a contralateral nerve section on the right side but that has not seemed necessary The only reason we were able to do these repeated catheterizations is because the man is still on total disability insurance from the fire department, although he is working every day selling insurance

The only complicating element in this case is that an upper dorsal sympathectomy was *done during the same operation on* the left chest with removal of the second through the fifth sympathetic ganglion to ensure relief from the precordial pain However, that should have had no effect on the pulmonary pressure

DR AARON HIMMELSTEIN, New York—The control of the pulmonary circulation is an intriguing problem, particularly in investigation of the normal levels If we stop to think how beautifully the correlation between ventilation and circulation is maintained in this low pressure system, and that very subtle changes in resistance in one small area of lung will tend to shift blood either into or away from that area of lung I think we might pursue the problem of the control of pulmonary artery pressures, and more particularly of the control of local areas of resistance by less than complete denervation of both lungs If we would attempt to denervate only one lung and then see if we can show that blood is circulating in greater or lesser volume through that lung is indicated by either rising or lowered oxygen consumption to that lung or if possible, to a segment of it we might have some idea of how the circulation is controlled rather than by attempting only to measure gross pulmonary artery pressures Studies under stress of exercise or anoxia or drugs might then be added

With that in mind we have undertaken to denervate one lung in dogs by division and resuture of the bronchus to one lung In the first group of dogs we have divided everything but the vessels and then stripped the vessels That was done because the division and suture of the vessel might in itself cause some change in the flow through these vessels When we studied a small group of these animals by bronchospirometry and put stress on the system with anoxia (since we do know that anoxia in human beings and in animals does cause pulmonary hypertension by increase of resistance and in severe anoxia of flow) we were unable to show that in the preparations just described that there was any detectable shift in oxygen consumption, either normally or when stress was applied to one lung or both lungs using low oxygen gas mixtures

DR MAX G CARTER New Haven.—All of us who have anything to do with cardiac catheterization realize how very complex this problem is and I personally am very happy to know that Dr Kaunitz is attacking it in this fundamental manner I would like to ask him just two questions Does he have any evidence that the lowering in pulmonary artery pressure is on a long term basis? The second question and I really wish Dr Wright would discuss these problems and ask questions himself is what changes if any may have been effected in the pulmonary volumina by this operation? I got the impression from the primary preoperative tracing showing the Hering Breuer reflex, that when the reflex was instituted at the inspiratory level and the lung broke away on the opposite side and reassumed its respiratory rhythm, it did so at a higher level of residual air It seems to me it would be of value to know if it can be done without too much difficulty whether or not any of the changes in pulmonary artery pressure are related to changes in pulmonary volumina particularly residual volume

DR KAUNITZ (Closing) —I would like to thank the discussers very much for their interest in this subject In answer to Dr Beatty we did not do controls on these dogs because the final studies were done anywhere from four to ten to twelve weeks after the second operation, at which time the dogs were running around the kennel and we thought we had normal dogs except for the operations As I mentioned fluoroscopic and x ray studies at the time of the final cardiac catheterization showed an apparently normal lung field.

We attempted to limit this denervation to one system and did not do a complete plexus resection in order to get at some of the answers We thought that by removal of both sympathetic and parasympathetic nerves to a lung little change would result because of the balancing effect of antagonistic denervations

In answer to Dr Carter, it is difficult to draw any conclusions from the one tracing you saw Actually if we let the dog breathe for awhile both lungs returned to their normal level of respiration, and I do not think there was any change in the residual volumes

We merely wished to present the results of this little experiment and we cannot, of course, draw any conclusions from it There is much further work necessary in this field

FOURTEEN YEARS' EXPERIENCE WITH CARDIOPEXY IN THE TREATMENT OF CORONARY ARTERY DISEASE

Samuel A. Thompson, M.D., F.A.C.S.,* and Aaron Plachta, M.D.**
(By invitation)
New York, N. Y.

CARDIOPEXY is an operation used to increase the blood supply of the myocardium.[1] This method was developed and perfected by animal experimentation and adopted because it could overcome the effects of a sudden complete ligation of one of the coronary arteries, and the same ligation, without the operation preceding it, resulted in a mortality of 50 per cent. The operation thus appeared to be of value in decreasing the seriousness of a coronary closure.[2]

In our animal experiments, we found that the insertion of a nonabsorbable and irritating substance, namely, magnesium silicate powder (U.S.P. Talc), within the pericardial sac, produced a foreign body reaction which had several characteristics. First, there was a marked hyperemia of the myocardium with dilatation of pre-existing blood vessels and the formation of new blood vessels within the myocardium. Second, a foreign body granuloma was produced which involved the pericardium and superficial surface of the myocardium. Third, adhesive granulomatous pericarditis without constriction took place, and the myocardial blood supply was further enhanced by the anastomosis of the extracardiac vessels from the mediastinal structures with the myocardial vessels through the bridge of the granulomatous pericarditis. This acute inflammatory reaction terminated in a chronic, adhesive granulomatous pericarditis with extracardiac and intracardiac vascular anastomoses, which were known to persist for ten years; we believe the *chronic lesion will remain active as long as the individual lives.* Since the particles of the magnesium silicate powder are not absorbed and very little is removed by the lymphatics or phagocytes, the greater part of the powder remains fixed in the adherent tissues of the pericardium and myocardium and serves as a constant and continuous source of irritation, hyperemia, and stimulation in the formation of new extra- and intracardiac blood vessels.

The possibility has occurred to us, that the granulomatous tissue might eventually change into scar tissue and with the passage of time, become avascular and thus afford no collateral circulation. We do not believe this takes place, and our opinion is based on a study of material dealing with human beings which was collected over a period of fourteen years; the material consists of ten necropsies. The patients were both men and women; their ages ranged between 40 and 64 years. The survival of these patients following cardiopexy was from one day to ten years.[3]

Read at the Thirty-third Annual Meeting of The American Association for Thoracic Surgery, San Francisco, Calif., March 27, 28 and 30, 1953.

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In the study of these hearts, done by Dr Plachta, a new technique was used which will be reported in a later paper[1] Visual dissection, a thorough x-ray study using a colored radiopaque material, and a serial section microscopic study was carried out of the myocardium, pericardium, lungs, and diaphragm

The lesion was characterized by a hyperemia of the pericardium extending into the myocardium and out into the surrounding mediastinal structures The vessels of the pericardium anastomosed freely with the vessels of the mediastinal structures, as well as with the intercoronary vessels The striking features of the granulomatous pericarditis were the persistence of the hyperemia, the uniformity and stability of the anastomotic blood vessels, and the presence of the talc crystals The adhesive pericarditis was movable and permitted adequate cardiac mobility These features did not deviate within a ten-year period of time (Figs 1, 2, and 3)

Occasionally the lesion which follows cardiopexy has been compared to and described as similar to the lesion seen in constrictive pericarditis Such a comparison is erroneous and far from the actual facts In constrictive pericarditis the pericardium may or may not be adherent, but it is usually thickened and avascular When the pericardium is removed from the myocardium little or no bleeding occurs However, following cardiopexy, the pericardium is always adherent, has never been found to constrict or impede the myocardium in any degree, and is excessively vascular and hyperemic When the pericardium is separated from the myocardium it is done with great difficulty as no distinct line of cleavage can be developed and bleeding occurs from both pericardial and myocardial surfaces This condition was found to exist not only in the animal experiments but also in one patient who was explored four and one-half years following a cardiopexy The necropsy studies up to ten years after cardiopexy also show the lack of similarity between the two conditions None of our postoperative patients have ever exhibited any of the cardinal signs of constriction such as prominent neck veins, hepatomegaly and ascites, hypotension and increased venous pressure, and fluoroscopically fixed cardia

During the past few years we have severely limited the indications for operation and accepted only those patients who were more or less terminal cases of coronary disease with a marked degree of disability[2] In view of the results which have been obtained we now believe that with more liberal indications, the operation can be successfully applied to a much larger group of patients Since the rationale of the operation is to produce a myocardial hyperemia, it could be used to counteract the effects of those lesions which produce myocardial ischemia The majority of lesions producing ischemia fall into three groups, namely, coronary artery disease, hypertension, and rheumatic disease Together they are responsible for about three-fourths of all cardiovascular deaths

The indications for cardiopexy in coronary artery disease are prophylactic, actual, and palliative A young individual with coronary disease, with

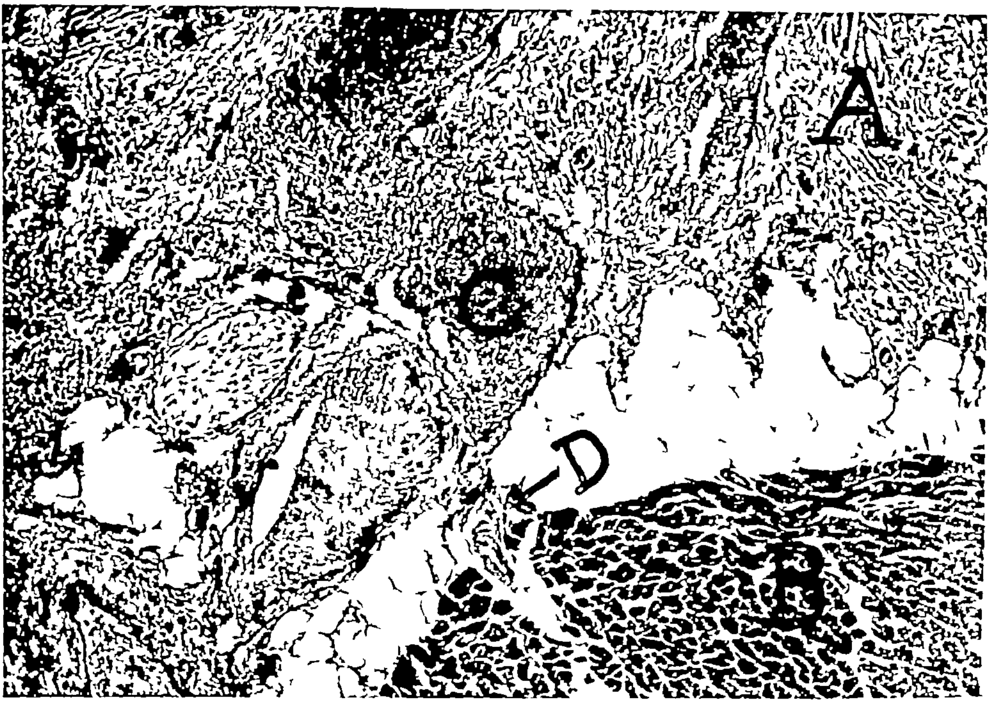

Fig 1—Microphotograph (×160) ten years after cardiopexy The granulomatous pericarditis is still active and vascular and contains the particles of powder which are seen best with a Polaroid filter (Fig 2) *A* The zone of granulomatous tissue containing numerous blood vessels *B*, The myocardium *C*, A large blood vessel traversing the granulomatous area and connecting with a myocardial blood vessel at *D*

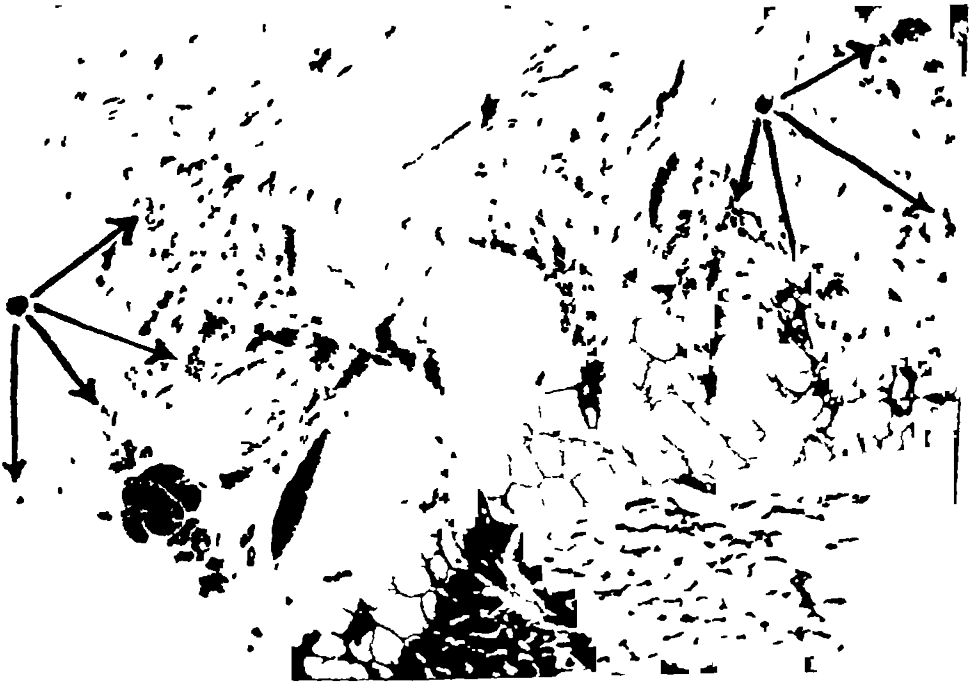

Fig 2—The same microphotograph as shown in Fig 1 but with a Polaroid filter added The magnesium silicate (talc) crystals can still be seen scattered through the granulomatous tissue.

no hypertension, without valvular involvement, and without a previous infarction is an example of a prophylactic indication An older individual with marked angina, with one or more previous infarctions with hypertension or valvular involvement with beginning congestive failure, and more or less completely incapacitated is an example of a palliative indication Between these two examples, probably lies the greatest usefulness of cardiopexy in coronary artery disease

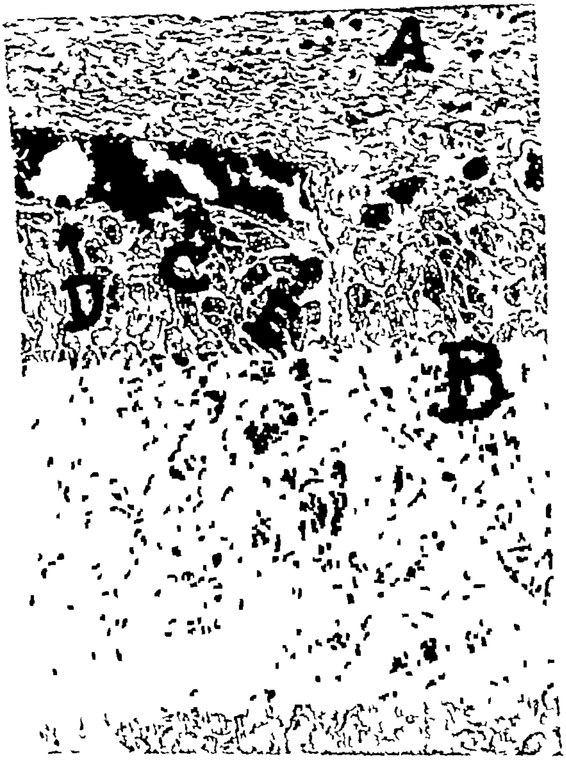

Fig 3 —Photomicrograph (×70) seven and one-half years after cardiopexy The granulomatous tissue contains numerous blood vessels and talc crystals There are several large blood vessels between the myocardium and the granulomatous tissue connecting with myocardial blood vessels *A* Granulomatous pericarditis *B* Myocardium *C* Large blood vessels connecting at two places with myocardial blood vessels at *D* and *E*

It is a matter of record that the majority of hypertensive patients die a cardiac death[4] Some of these patients die from congestive failure and in many of these instances, myocardial ischemia is the predominating factor Many of these patients with hypertensive disease develop a marked angina which may be indicative of a relative coronary insufficiency rather than actual coronary disease In 500 hypertensive patients operated upon by Hinton and reported by Thorp,[5] myocardial ischemia as evidenced by angina and previous infarctions, was the chief complaint before the operation in more than 30 per cent of the patients Hypertension has been reported by many groups to exist prior to myocardial infarction in from 23 per cent to 73 per cent of the cases[6] Still in other cases of hypertensive disease, with no angina, with no evidence of congestive failure, but with a marked enlargement of the heart and the electrocardiogram demonstrating a definite left axis deviation and a positive Master two step test, the finding of these signs indicates a myocardial ischemia Therefore the indications for cardiopexy in hypertensive disease are when angina is present, when there has been a previous infarction, when beginning heart failure is evident, and when there is no congestive failure and no angina but the heart is enlarged and the electrocardiogram shows a marked enlargement of the left ventricle with a positive Master two step test

The clinical features or symptoms in chronic rheumatic valvular disease are due as much to the state of the myocardium as they are due to the valvular involvement Severe valvular involvement or even multiple valvular involvement is compatible with life so long as the heart muscle remains relatively strong Rheumatic disease produces three principal changes in the heart changes in the valves, changes in the coronary arteries, and changes in the myocardium The valvular changes result in stenosis or regurgitation or a combination of the two The myocardial changes are a low-grade inflammation resulting in fibrosis and ischemia Rheumatic fever regularly produces changes in the coronary arteries, inflammatory or fibrotic lesions or both are constantly observed, and myocardial damage is associated with these arterial lesions[7] The decision for or against the surgical treatment of chronic valvular disease requires a careful estimation of the degree of valvular dysfunction as well as the myocardial dysfunction The possibility of treating myocardial dysfunction as a primary object in chronic valvular disease has been completely overlooked until recently A few years ago Gorelik[8] became convinced that many of the symptoms observed in chronic valvular diseases were due more to myocardial ischemia than they were to the valvular disorder and he was the first to use cardiopexy as a treatment in chronic rheumatic valvular disease

Whenever possible in valvular stenosis a splitting or cutting of the valve commissure should be done However, there are times when such a procedure may not be indicated because of marked myocardial damage, and a damaged left ventricle may be unable to carry the increased load following the relief of the obstruction[9] Marked regurgitation associated with the mitral stenosis is also a contraindication for commissurotomy, as is prolonged pulmonary hypertension with the development of pulmonary arteriosclerosis Associated valve lesions such as aortic stenosis, as well as prolonged passive congestion due to right heart failure with marked liver changes, make mitral surgery impractical It is at such a time that the surgical treatment can best be directed toward revascularization of the heart and restoration of myocardial function Because cardiopexy produces a myocardial hyperemia, it aids in the restoration of the myocardial function and is indicated in those conditions described previously where commissurotomy is not suitable In some of these patients who have had cardiopexy, the improvement has been so marked that the patients later became satisfactory candidates for commissurotomy

The contraindications would include those systemic and cardiac conditions where the risk is quite evidently too great for any type of operative procedure such as advanced renal and hepatic disease and extreme debilitation A recent myocardial infarction is a definite contraindication and remains so until such time as the infarcted area has become well healed and we have arbitrarily set a minimum time of three months Marked and intractable congestive failure, where cyanosis is present at rest, is also a contraindication

The operation has been fully described in previous articles[1], I will not now describe it more than to say that it consists of removing a portion of the fifth costal cartilage on the left side of the chest At this site the pleura is not entered The pericardial sac is opened, the pericardial fluid is aspirated as completely as possible and from 2 to 4 dr of dry magnesium silicate powder is spread widely over the surface of the myocardium The tissues are then closed in anatomic layers without drainage It is a simple operation and requires about thirty minutes for its performance

We have recently made a fourteen-year follow-up study of our patients who have had a cardiopexy [10] In order to determine fully the effects of the operation, no patient has been included in this series who has been operated upon during the past twelve months The total number of operations was fifty-seven Deaths attributed to the operation and all hospital deaths after the operation numbered seven, giving an operative and hospital mortality of slightly more than 12 per cent Thirty-three of the patients, or 66 per cent, are living at the present time

Of the remaining fifty patients, who have been followed up to the present time, or the time of their death, thirty-seven were men and thirteen were women. This is a ratio of slightly less than three to one The youngest patient was a woman 35 years old, and the oldest was a woman 68 years of age The average age of the entire group was 51 years, and the majority of patients were in the sixth decade The shortest duration of symptoms before the operation was three months and the longest was fifteen years, giving an average of three and one-half years There is a sharp difference, however, in the duration of symptoms of the patients who are still living and in those who have died The living patients averaged symptoms for two and three-quarter years while the patients who have died averaged symptoms for four and one-half years before operation

In thirty-seven patients, angina occurred as the first symptom, and coronary occlusion was the first symptom in thirteen Three of the patients had congestive failure, and seven had hypertensive disease

The shortest length of life after the operation was two months and the longest is now over fourteen years, with an average of five years plus However, thirty-three of the patients are still living so this average is subject to a change as time goes on

Of the seventeen patients who were followed up to the time of their death, the average duration of symptoms before operation was four and one-half years and the average life span after operation was five years Thus the span of life of these patients from the first symptom was nine and one-half years. This compares very favorably with the span of life of the average coronary patient who is *not operated upon*. Statistics upon these patients vary with each group reported, but averaging the groups gives a life span of four to five years from the onset of the first symptom. Factors such as cardiac enlargement, hypertension, infarction, congestive failure, and conduction defects in coronary disease indicate a much less favorable prognosis; some of our patients had all of these conditions, and all had some of the conditions.

Our group of patients is small and no definite conclusions should be drawn from a small group. We nevertheless believe that the span of life for these patients has been markedly increased by the operation for two reasons. First, the average length of life for these patients was nine and one-half years compared to four and one-half for the average nonoperated coronary patient. Second, the large majority of these operated patients were terminal cases, completely incapacitated, having been through one or more occlusions and very few of them were good surgical risks or could be presumed to continue life for any length of time. They had already lived for four and one-half years and were thus at the end of the average life span for coronary patients, yet they continued to live after the operation for an additional average of five years.

There are four tests which we use to determine the postoperative benefits. First, the decrease in the amount of anginal pain. Second, the increase in the exercise tolerance. Third, the improved ability to attend to their daily needs. Fourth, a return to their former or some gainful, occupation. Using these four tests as a guide we have divided the patients into three groups. The first group having less than 50 per cent improvement we classify as poor results. The second group having from 50 to 75 per cent improvement we classify as moderate results. The third group having more than 75 per cent improvement we classify as having marked results.

Of the fifty patients followed, five or ten per cent have received less than 50 per cent improvement. The remaining forty-five patients, or 90 per cent of the group, have received more than 50 per cent improvement. Twenty of these patients, or 40 per cent of the group, have received more than 75 per cent improvement as measured by the four tests and are classed as markedly improved.

The postoperative electrocardiographic changes are usually confined to the immediate postoperative period of several weeks.[1, 2] The changes are those characteristic of acute pericardial reaction and consist of an elevation of the RS-T segment with a downward concavity of the S-T segment. The changes revert to the preoperative pattern after several weeks. None of the patients in this series had a normal electrocardiogram before the operation, nor did the electrocardiogram return to normal after the operation. The electrocardiographic recovery does not appear to be as important a factor in the prognosis as does the clinical recovery.[11]

Objective evidence of the mediastinitis is obtained by means of serial x-ray films The characteristic changes are a widening and increased density of the mediastinal shadow together with some increased markings in both lower lobes of the lungs These changes revert to normal in about two or three weeks

CONCLUSIONS

For a group of patients who were medical failures, this operation has produced most satisfactory results It should be emphasized that almost all of the patients were terminal cardiac cases and more or less completely incapacitated. Few of them were satisfactory as surgical risks As a result of the operation we were able to rehabilitate these patients so that 90 per cent of them were improved more than 50 per cent, and 40 per cent are more than 75 per cent improved

In addition to their physical improvement the patients who later on died, lived an average length of life after the operation of five years giving them an average life span of nine and one-half years from the onset of the first symptoms We do not believe that these patients would have survived this length of time without the operation.

I am grateful to Dr Milton J Raisbeck Department of Cardiology of the New York Medical College for his generous cooperation and for the selection and medical management of most of these patients before during and after the operation

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DISCUSSION

DR H BRODIE STEPHENS, San Francisco—I wonder if Dr Thompson will tell us if any of the patients that died following operation came to necropsy and if so if any of them died from coronary occlusion

DR GABRIEL SELEY, New York—I have followed Dr Thompson s work with a great deal of interest, and I would like to ask him at this time whether or not it would be feasible to perform this procedure in a much simpler manner In other words, since the object of the operation is to aspirate pericardial fluid and introduce a talc powder, could this not be done through a large bore aspirating needle, using a powder insufflator or some other mechanism

DR THOMPSON (Closing) —I would like to thank Dr Stephens and Dr Seley These patients have had subsequent coronary attacks and subsequent closures, following cardiopexy They have not suffered too severely from those occlusions They have died from a variety of causes We have never, in any of the ten necropsies which we were able to get, found any fresh infarctions We suppose that two of the patients who apparently died from fibrillation, would probably have had infarctions if they had survived the attack, but there was no evidence of acute infarction at the time of necropsy

About simplification of the operation I would like to say that in the animal laboratory we found it impossible to produce the same results if we tried to dilute the powder with any type of vehicle We tried various salines and other carriers, and we found that the tendency is for the powder to wash down in the dependent part of the pericardial sac, and when this occurs we get incomplete pericardial adhesions and a very limited area of granulomatous tissue formation We like to have the adhesions and granulomatous tissue completely surround the heart It is very difficult to insert a trocar in the pericardial sac, it is sometimes difficult even to pick up the pericardial sac with hemostats, because it is stretched very tightly over the heart like the head of a drum I think the danger of trying to simplify this further would outweigh the actual simplicity of the operation

CARDIAC SURGERY UNDER HYPOTHERMIA

Charles P Bailey, M.D, Brian A Cookson, M B, Ch B (Edin)
(by invitation), Daniel F Downing, M.D (by invitation), and
Wilford B Neptune, M D (by invitation)
Philadelphia, Pa

HYPOTHERMIA may be defined as a physical state in which the body temperature is below the normal range Artificial hypothermia, as it will be discussed here, refers to the selective lowering of the temperature by physical means For the purposes of cardiac surgery we may consider that the proper state is achieved below 90° F (32 2° C), preferably between 74° and 80° F (23 3° C and 26 6° C) Temperatures appreciably below 70° F (21 1° C) while used experimentally, tend to depress the vigor of cardiac contractions and function to such a low level that the damaged human myocardium associated with serious anatomic cardiac defects probably could not accept the ordeal and subsequently recover full function

The value of low body temperature in cardiac surgery is twofold 1 At low temperatures the tissue demand for oxygen is significantly depressed This varies almost directly with the degree of cooling The circulation, therefore, may be greatly slowed or even completely interrupted for a relatively long period of time without evidence of damage to brain, kidneys, or other viscera 2 Myocardial activity is depressed Its demands for oxygen are so reduced that a blood supply which would lead to ischemia and damage at normal temperatures is well tolerated. It is probable that for each individual there is a critical temperature level below which function may be depressed to an irreversible degree It is evident that the infantile heart is much better able to tolerate very low temperatures and to recover from them than is the adult heart

The idea of possible clinical application of hypothermia is not new There is a large body of medical literature covering the experimental and clinical use of hypothermia The work of Fay[1] and Talbot[2] in the clinical field is fundamental McQuiston[3] and Potts[4] have already reported its use in clinical cardiac surgery

In the laboratory the possibilities of hypothermia have been rather fully explored[5, 6] Following the lead of Bigelow and his associates,[7-9] we, too, have undertaken extensive investigations in the field of experimental cardiac surgery[10, 11] It was found possible to lower the body temperature of dogs to such a degree that the venae cavae could be clamped and the right heart opened for prolonged periods with the survival of the animals and with no

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subsequent evidence of organ damage (Fig 1) Opening of the left side of the heart on the other hand, was frequently attended by the development of coronary, cerebral, or systemic arterial air embolism It was realized that this risk was inherent in the application of open surgical techniques to the left side of the heart and not really to the hypothermia itself Attempts to use the so called "mechanical heart" to permit open surgery of the left atrium or left ventricle are similarly attended by a high incidence of arterial air embolism

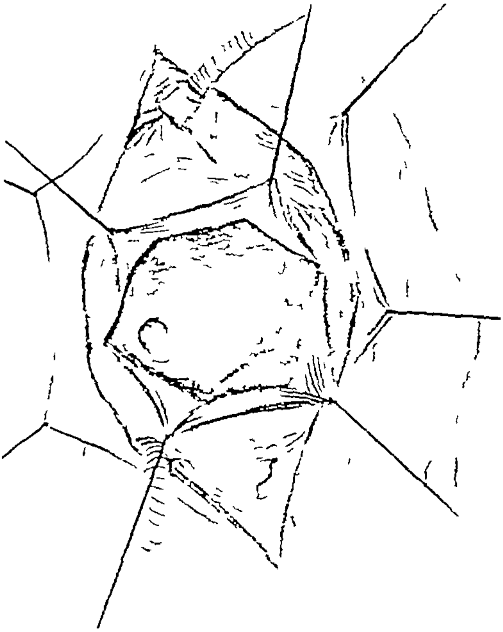

Fig 1 —Wide opening of right atrial chamber after intrapericardial tourniquet compression of both venae cavae for intracardiac surgery under direct vision This is feasible under hypothermia

The use of arterial transfusions to maintain a high pressure in the aortic arch was found to reduce the incidence of such air embolism significantly, apparently by keeping the aortic valves closed while the left ventricle was open to the air (Fig 2) In this connection it is important to point out that citrated blood so used appears to be quite toxic to the heart rapidly producing ventricular fibrillation Red cells suspended in Gelatin Ringer solution* appear to have no such deleterious effect[17] It may be found desirable in the future to use only such nontoxic suspensions of red cells in routine arterial transfusions Probably some unexplained deaths occurring in the clinical use of arterial transfusion may be attributed to the direct entrance of citrated blood into the coronary arteries

It also appears that the use of arterial transfusions significantly prolongs the period at any given body temperature during which the circulation may be completely clamped off, by perfusing the brain, the coronaries and other parts of the circulation. Thus, while twelve minutes has been considered the maximum safe time for clamping the venae cavae in dogs at 76° F (24.4° C) twenty minutes is perfectly safe with a rapid arterial transfusion.[12]

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*Modified fluid gelatin No 8 generously supplied free by Dr Tourtelotte of the Knox Gelatin Company Camden N J

We have attempted to translate these experimental observations in terms of human beings. Our first problem was the selection of suitable individuals for surgery under hypothermia.

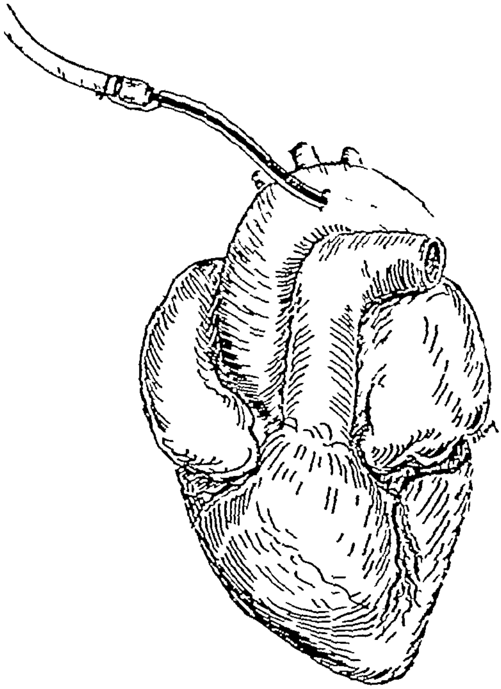


Fig 2—Direct intra aortic transfusion of red blood cells suspended in Gelatin-Ringer solution. This perfusion of the coronaries and cerebral vessels permits prolongation of the time of circulatory interruption at any temperature level. Also the fluid pressure closes the aortic valve lessening the risk of air embolism when the left ventricle is opened.

At the present time there exist many techniques of closed or digital intracardiac surgery,[13-21] which are satisfactory for the moment. However, there is a strong feeling that several of the operations could be considerably improved upon if they could be performed by an open technique under direct vision. For instance catheterization studies some time after operative relief of the obstruction in isolated pulmonic stenosis (either valvular or infundibular) by the Brock technique nearly always show a residual pressure differential between the right ventricle and the pulmonary artery. While great clinical improvement has usually been obtained by this procedure, it is obvious that the obstruction has been incompletely relieved. Undoubtedly, a more complete relief could be obtained by an open technique.

Such an open technique might be feasible by the use of a "heart-lung" apparatus but could be equally well accomplished by the simpler method of hypothermia Since the "heart-lung" is not yet sufficiently perfected for clinical use, it would seem logical to use hypothermia for this purpose

While hypothermia does permit the performance of such procedures, in its present stage of imperfection, many of the older techniques are still preferable As the imperfections of hypothermia and methods of managing it are progressively remedied, there will probably be a gradual switch-over to the new techniques of operation under direct vision In this earliest phase of the development of hypothermia we can justifiably apply it only to problems for which there is no other answer or as an adjunct to orthodox surgical techniques

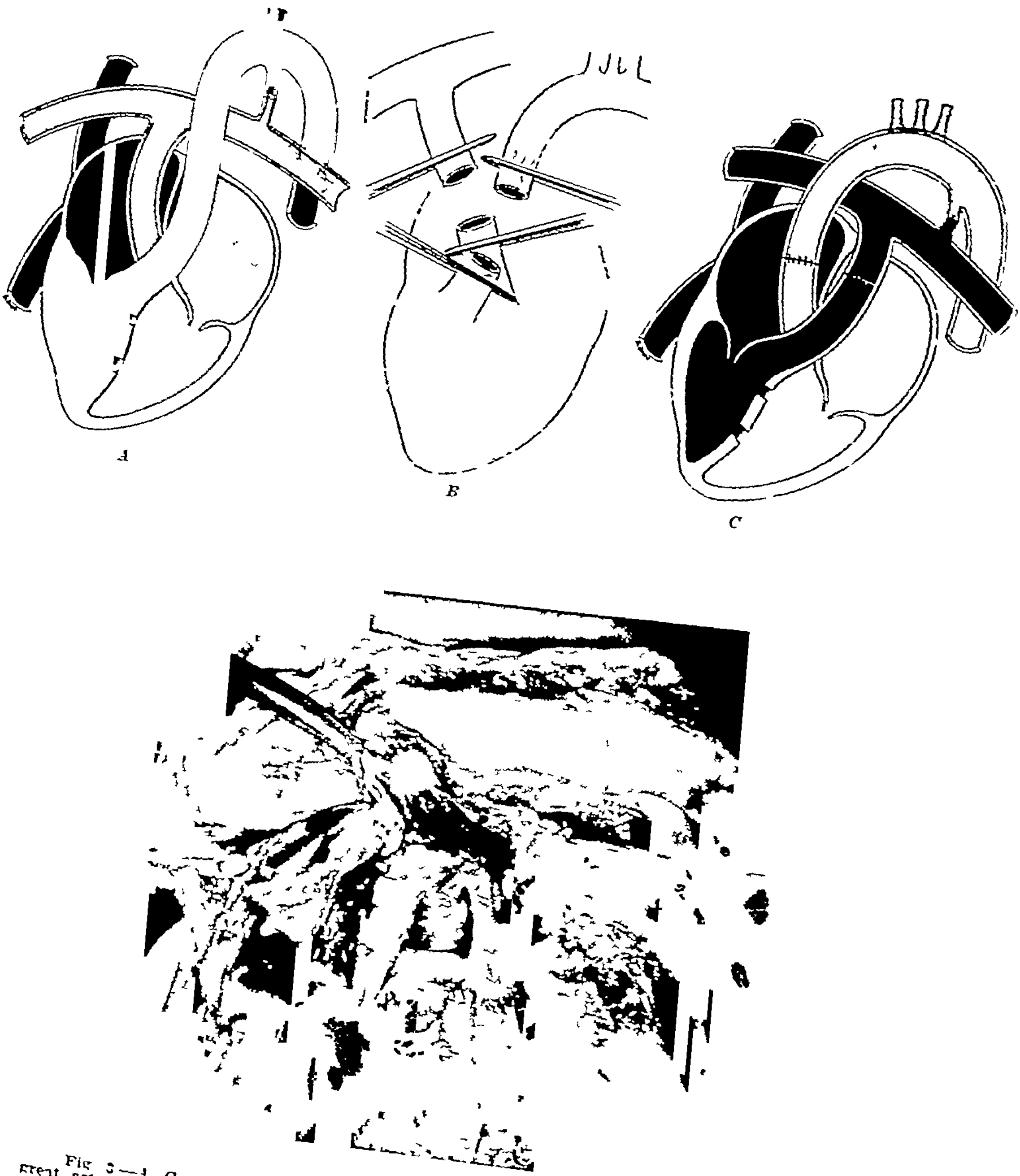
While we early realized the danger of opening the right atrium in patients with a large interatrial communication, we were originally of the opinion that the very primitive low defect of the interatrial septum, known as persistent ostium primum, could be corrected only by an open technique We now realize that a slight modification of the technique of atrio-septo pexy[10] originally described for the surgical closure of defects of the septum secundum (effective in thirteen of fifteen such patients operated on by us to date) is eminently satisfactory for the complete obliteration of the persistent ostium primum

The first patient (H D) chosen for the open technique had a very large persistent ostium primum The right atrium was widely opened on Aug 29, 1952, and the defect was closed by direct suturing However, an embolism to the coronaries caused the onset of ventricular fibrillation which proved irreversible

Since that time hypothermia has been employed in twelve additional cases of serious heart disease, an open technique was employed in three, while a closed technique was used in the others Actually, three classified as closed were patients with transposition of the great arteries which were treated by division between clamps and cross anastomosis (Fig 3, *A*, *B*, *C*, and *D*)

The results in our entire series are summarized in Tables I, II, and III It will be evident that the over-all surgical mortality has been prohibitive (69 2 per cent) The possible extenuating factors are the severity of the lesions (five congenital transpositions) and the condition of the patients so operated Among the surviving patients it was felt that B L and S G were so ill that they could not have survived orthodox surgery (Brock infundibulectomy) except with the help of hypothermia M A F certainly could not have had her interventricular septal defect corrected except by open surgery under hypothermia J S probably would have done equally well with a standard atrio septo pexy performed at normal body temperature We feel that K C one of the patients treated by division and reanastomosis of the transposed aorta and pulmonary artery undoubtedly would have lived and done well had he not developed a cardiac arrest during a postoperative bronchoscopy for retained secretions (thirty hours later)

However the operative death of two similarly treated patients with transposition included in this series has convinced us that this particular surgical approach is basically unsound since the coronary arteries nearly always arise



A B C

D

Fig 3—A Case of K C Schematic diagram of his circulation B Division of both great arteries between clamps C Circulatory arrangement after crossed reanastomosis in K. C D Autopsy appearance of great vessels in K. C Note the considerable discrepancy in the caliber of the vessels

CASE 5 —S G, a 12 month old white female infant, had a history of cyanosis from birth Tachycardia had always been noted She tired easily and more recently had become quite dyspneic A diagnosis of the tetralogy of Fallot was made on clinical and roentgen findings as the infant's condition was thought to be too critical for cardiac catheterization On Oct 3, 1952, under hypothermia at 80° F (26 6° C), resection of the infundibular stenosis was carried out via closed technique The result of the operation was exceedingly gratifying It was thought that due to her extremely critical (practically terminal) condition, hypothermia might well have made possible her survival

CASE 6 —M F, a 15 year old white girl, was admitted with a history of a heart murmur since birth but no signs nor symptoms of congestive failure Cardiac catheterization revealed an interventricular defect On March 13, 1953, under hypothermia at 76° F (24 4° C), the defect was sutured by an open technique utilizing an incision in the right ventricle The patient developed ventricular fibrillation as the ventricular incision was being closed, but was restored to a normal rhythm by massage alone Convalescence has been satisfactory to date At surgery it was felt that the defect had been completely closed

CASE 7 —B L was a 2½ year old Negro girl with a history of cyanosis and cardiac murmur since birth On admission she was markedly cyanotic, dyspneic, and demonstrated easy fatigability Cardiac catheterization and angiography substantiated a diagnosis of transposition of the great vessels The possibility of transposition of the aorta and levoposition of the pulmonary artery was considered On Nov 12, 1952, under hypothermia at 72° F (22 2° C), surgery was carried out It was found that the patient had transposition of the aorta, high ventricular septal defect with levoposition of the pulmonary artery, and congenital fusion of the pulmonic cusps Using the closed technique, pulmonary valvulotomy was carried out Her postoperative course has been very satisfactory

CASE 8 —K C, a 7 month old Negro boy, had a history of cyanosis since birth A diagnosis of pulmonary stenosis and patent foramen ovale was made on incomplete cardiac catheterization On Nov 10, 1952, under hypothermia at 71° F (21 6° C), it was found that transposition of the great vessels existed A switch over anastomosis was done the circulation being occluded for twenty two minutes Ventricular fibrillation occurred once, but a normal rhythm was restored The patient was awake and crying three hours postoperatively He developed cardiac arrest thirty hours postoperatively during a routine bronchoscopy for retained secretions It was felt that he would have continued to do well if this accident had not occurred The coronary arteries arose from the right ventricular vessel A large ventricular septal defect existed

CASE 9 —G N, a 3½ month old white boy, had had recurrent bouts of cyanosis and dyspnea since birth Cardiac catheterization was attempted but discontinued because of the patient's poor condition On clinical and roentgen examination, he was thought to have transposition of the great vessels On March 6, 1953 a switch over anastomosis was done under hypothermia at 72° F (22 2° C) The circulation was occluded for a total of twenty minutes The heart action was extremely poor by the time the second anastomosis was completed Heart action continued for two hours with the assistance of an electrical pacemaker At post mortem examination the coronary arteries were found *to arise from the right ventricular* vessel There were a 0 7 cm high septal defect and a patent ductus arteriosus The foramen ovale was closed

CASE 10 —C R was an 11 day old white girl who had been cyanotic and dyspneic since birth It was thought that the patient probably had transposition On Dec 24, 1952, under hypothermia at 72° F (22 2° C) transposition of the great vessels was found A switch over anastomosis was done the circulation being occluded for a total of twenty three minutes Heart action became poor and finally ceased The coronary arteries rose from the right ventricular vessel

CASE 11 —F K was a 10 month old white boy who had had a diagnosis of transposition of the great vessels made on cardiac catheterization prior to admission He had been cyanotic since birth On Nov 7 1952, under hypothermia at 78° F (25 5° C) the diagnosis was confirmed. The coronary vessels came off the artery arising from the right ventricle The circulation was interrupted for five minutes while a defect was made in the interatrial septum under open technique and direct visualization The heart beats were never strong after the atrium was closed After forty minutes of weak heart beats ventricular fibrillation occurred and a normal sinus rhythm could not be restored

CASE 12—T Y was a 33 year old white man with a definite history of rheumatic fever at the age of 10 years and dyspnea and substernal pain for nine months Preoperative work up including cardiac catheterization and brachial artery tracings led to a diagnosis of predominant aortic insufficiency, mild aortic stenosis and possibly slight mitral stenosis On Jan 20 1953 under hypothermia at 88° F (31 1° C), exploration of the aortic valve via the left ventricle was carried out prior to a planned attempt at direct repair of the valve. Ventricular fibrillation developed Using a mechanical pump, blood was pumped from the left auricle into the left subclavian artery for a short period while massage was carried out Normal sinus rhythm was restored for ten minutes Ventricular fibrillation developed again and when the pump was again used, the left ventricle filled with a large quantity of blood due to retrograde flow through the incompetent aortic valve The ventricle became so hard it could not be adequately massaged Normal sinus rhythm could not be restored

CASE 13—N S was a 31 year old white woman with progressive dyspnea, orthopnea and fatigability of three years' duration. Preliminary studies showed advanced mitral insufficiency On Sept 29, 1952, under hypothermia at 78° F (25 5° C), commissurorrhaphy (suturing the mitral leaflets together) was carried out During the intracardiac surgery cardiac arrest occurred followed by ventricular fibrillation which was resistant to all attempts at resuscitation Examination of the left atrium after death revealed a clot to be present which was absent at the beginning of surgery It was felt that the clot contributed to the onset of arrest and fibrillation However cardiac action had become extremely poor even before exploring the mitral valve

TECHNIQUE OF ADMINISTERING HYPOTHERMIA

Artificial lowering of the body temperature may be accomplished in many ways Immersion in cold water, packing in cracked ice, a "deep-freeze" type of cold chamber and a rubber blanket containing coils through which cold brine or other cool fluids may be circulated have been used Certain drugs may be administered to depress the function of the thermal center and so facilitate lowering the body temperature We are presently trying these drugs in experimental animals but they have not yet been used on our patients

We have had no experience with immersion (Fig 4)

We have used cracked ice applied directly to the patient's entire body both for the clinical treatment of hyperpyrexia and as an adjunct in cooling patients whose body temperature was slow to descend with other methods of refrigeration While messy direct application of cracked ice is quite effective (Fig 5)

The cold chamber even when adequate air circulation is available carries with it the threat of superficial frostbite or pressure gangrene because of the extreme coldness of the circulating air Proper protection of the superficial portions of the body and the extremities militates against effective application of the cooling air and hence, retards cooling (Fig 6)

The blanket with circulating coils developed by Fay[1] is by far the most satisfactory cooling mechanism (Fig 7) * By means of a compressor, or even an ordinary pump, cool liquid is circulated through the coils at any desired rate for rapid or slow cooling (Fig 8)

The blanket is placed on the operating table and is closed about the patient with a zipper When the desired temperature is reached, the blanket is opened but it is left in place under the patient while the operation is carried out (Figs 9*A* and 9*B*)

Fig 4

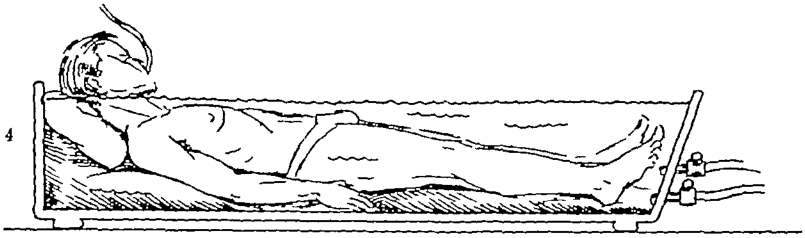


Fig 5

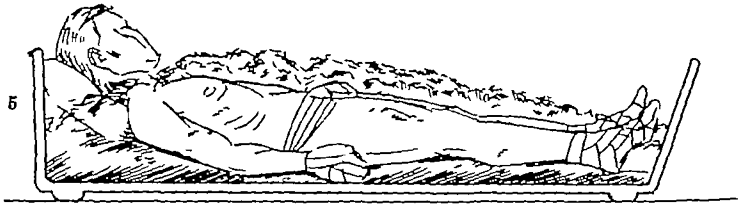


Fig 6

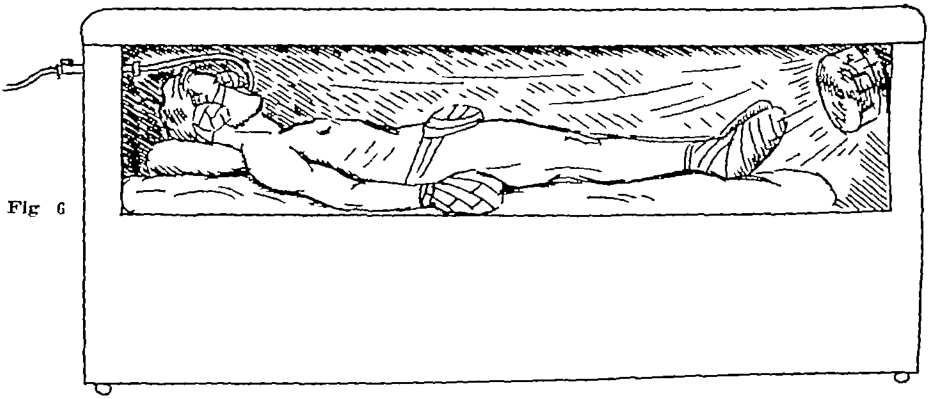


Fig 4 —Induction of hypothermia by immersion in cold water

Fig 5 —Induction of hypothermia by packing the patient in cracked ice While messy this method is very effective It is useful in treating hyperpyrexia from any cause. It is especially beneficial in the postoperative management of cyanotic patients particularly if they are running a fever

Fig 6 —Use of a cold chamber (deep freeze) to produce hypothermia Because of the extreme coldness of the air there is always danger of frostbite or gangrene of the extremities

After the definitive surgery is completed the cold fluid is replaced by warm water and the patient is rewarmed to a level where respiration is spontaneous and adequate This is usually at about 84° F (28 8° C) We have chosen

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*Obtainable from the Thermo Rite Products Corporation 1748 Main St. Buffalo N Y

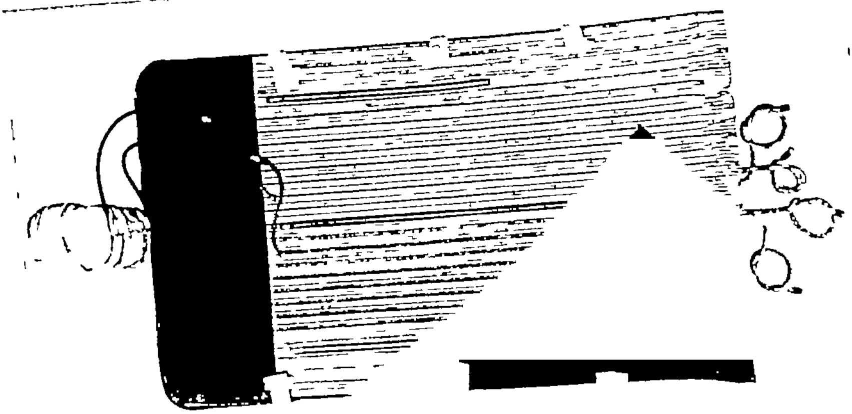


Fig 7—Rubber blanket with internal coils for the circulation of cold liquid provides the most satisfactory method of inducing hypothermia

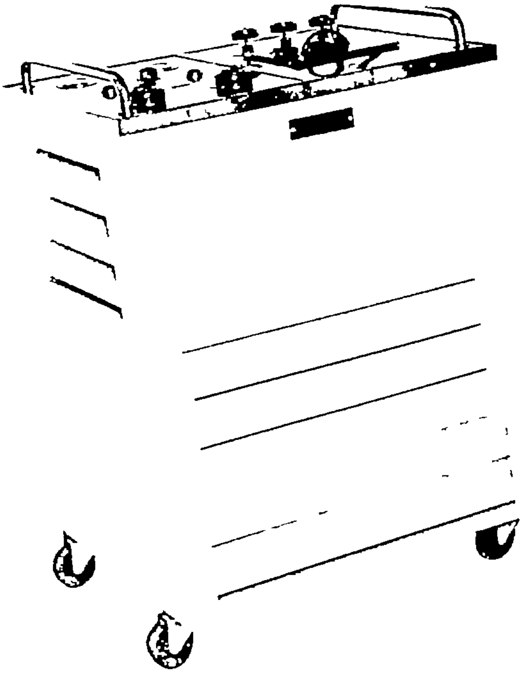


Fig 8—Compressor to provide circulation of either cool or warm (for rapid rewarming) fluids through the blanket.

to permit spontaneous (slow) rewarming to take place above this level It is usually complete in about twelve hours, but full consciousness may return at any time

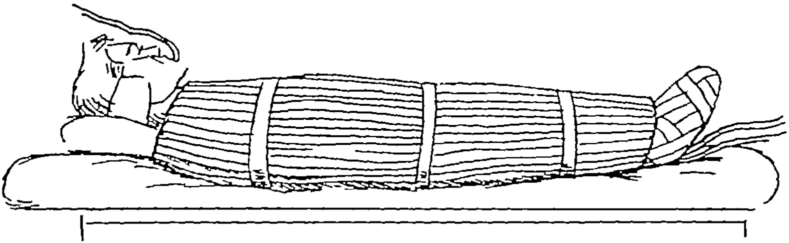


Fig 9A —Patient wrapped in cooling blanket.

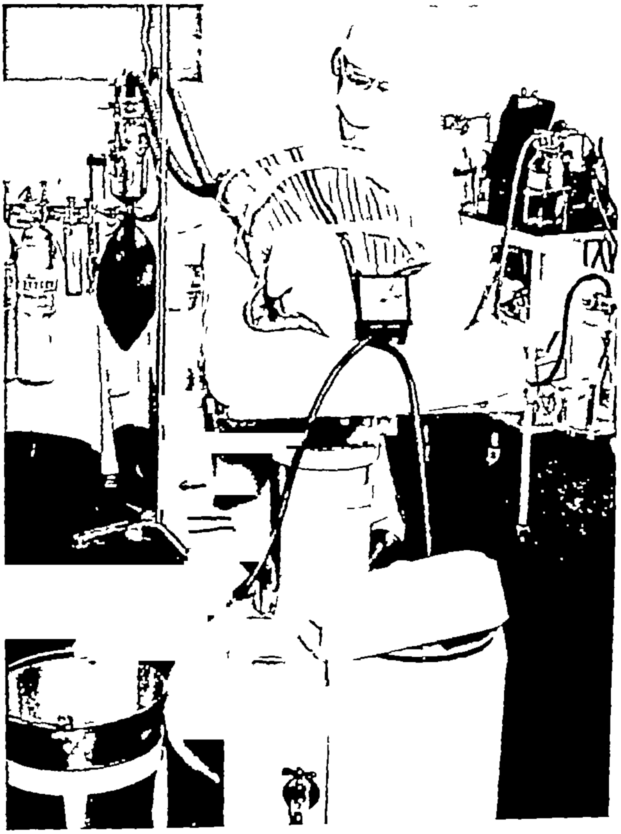


Fig 9B —Crude but inexpensive method of circulating cold brine through blanket by an ordinary water pump

Temperatures are taken rectally (or vaginally) either by a mercury thermometer, or preferably by a thermocouple A continuous recording thermocouple is very helpful

Anesthesia is essential in inducing hypothermia both to render it painless and to reduce the tendency to shivering which retards the cooling

Thiopental sodium and procaine are administered intravenously by the technique reported by Keown and his associates[27] An endotracheal tube is inserted and connected to a closed anesthesia system A direct writing electrocardiograph is used to detect the electrical waves associated with shivering Their appearance is an indication for the use of additional Pentothal Sodium No attempt is made to produce a deep level of anesthesia Frequently slight movements of the extremities occur even during the definitive portion of the surgery

The anesthesiologist takes over respiration as soon as spontaneous efforts cease or become ineffective, usually between 80° and 85° F This is rhythmically maintained by manual compression of the breathing bag except when the circulation is actually interrupted At that point pulmonary inflation is useless and the movements of the respiratory organs may hamper the surgeon As soon as the circulation is resumed the anesthesiologist again produces intermittent rhythmic lung inflation, continuing until spontaneous respiration returns and becomes adequate

Constant observation of the electrocardiographic record is essential since ventricular asystole or fibrillation may occur at any time during the cooling process

Adequate hypothermia may be established in infants within an hour Older children take longer, and adults may take four hours or more If the falling temperature stays at a given level for an hour or more, cracked ice may be poured into the blanket directly next to the patient's skin This is apparently harmless and is quite effective in increasing the rate of cooling

SURGICAL TECHNIQUE

Surgery under hypothermia is very similar to that at normal body temperatures once the surgeon becomes accustomed to the cold feel of the tissues Cold saline solution and cold wet sponges may cause a sense of strangeness to the members of the operating team

Incisional bleeding is less profuse than at normal temperatures, but is at least as persistent Ligation or electrocoagulation of bleeding points is just as essential for good hemostasis

The heart feels warmer than the other tissues It beats strongly although more slowly than usual

Ventricular fibrillation may supervene at any time, seeming to occur more readily than at normal temperatures Standstill is by no means rare Since the time factors required for re-establishment of the circulation are by no means as critical as at normal temperatures, either manual cardiac massage or defibrillatory measures may be temporarily postponed or may be applied very deliberately

Electric countershock is much more effective in producing defibrillation during hypothermia than at normal temperatures It may therefore even be considered advisable to permit the heart to fibrillate throughout the definitive portions of the surgery In the experimental laboratory we have sometimes deliberately induced standstill with acetylcholine or ventricular fibrillation by electric induction in order to ensure a quiet heart during the definitive maneuvers

It is considered good practice in human surgery to interrupt the circulation for as short a period of time as possible rather than to utilize the maximum possible at the particular level of hypothermia. Our longest period of complete circulatory interruption with recovery when using an open technique was six and one-half minutes (M. A. F.). Our longest complete circulatory interruption with the closed technique was twenty-two minutes (K. C.). While the patient did not finally recover (cardiac standstill during postoperative bronchoscopy) there was no evidence of cerebral damage thirty hours after surgery.

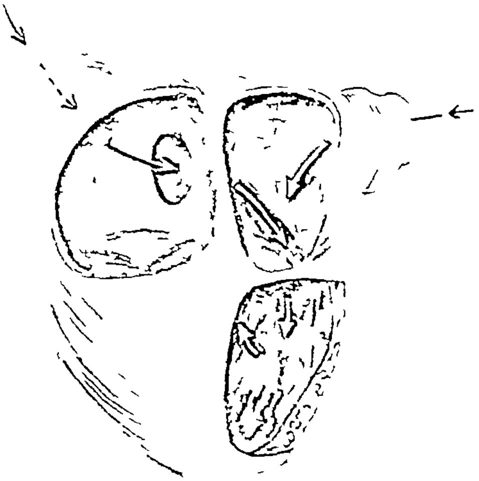


Fig. 10.—Ease (and pathways) of production of air embolism to the systemic arteries after opening the left side of the heart or after wide opening of a right cardiac chamber in the presence of a large septal defect. At the present time this great risk would seem to interdict the closure of atrial septal defects by an open technique.

It is now our practice routinely to administer a Gelatin-Ringer suspension of red cells directly into the aorta by way of a polythene tube throughout the period of circulation interruption (Fig. 2). We feel that this general arterial perfusion greatly lengthens the time of tolerable circulatory interruption and keeps the patient in much better condition during the actual surgery.

The usual thoracic operative incisions are the ones employed. Transection of the sternum and opening of both pleurae in the fourth interspace provide an ideal approach to the right side of the heart and the great blood vessels.

INDICATIONS FOR HYPOTHERMIA

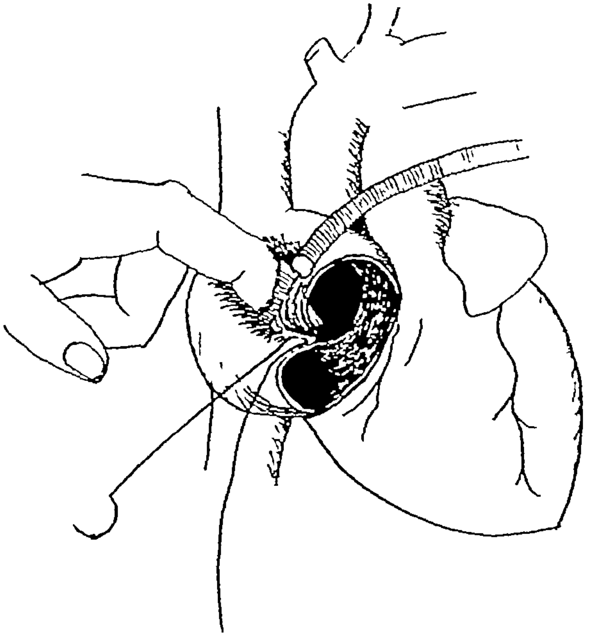
As a result of this small but intensively observed series of cases we have come to certain conclusions regarding the present indications for and contraindications to the use of hypothermia in cardiac surgery. We well realize that these considerations must change with progressive improvements which are to be expected as familiarity with this method increases.

At present we think hypothermia is indicated

1 In infants

A As an adjunct to orthodox surgery in severely cyanotic infants Probably the optimum range of temperature in this type of case

Fig 11



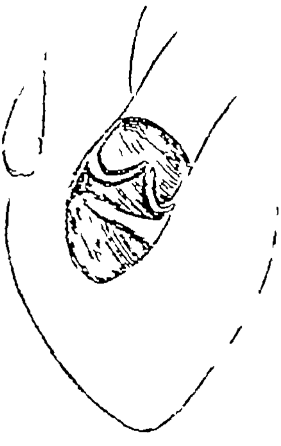


Fig 12

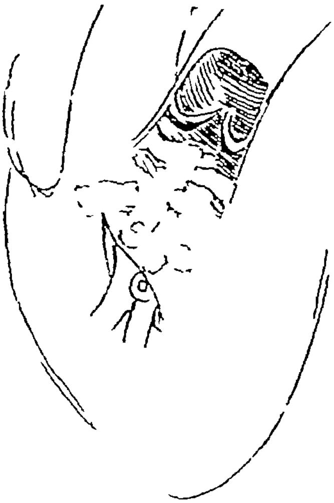


Fig 13

Fig 11 —Technique of atrio septo pexy which is so safe and satisfactory that hypothermia and open surgery would seem contraindicated

Fig 12.—Essential defects in tetralogy of Fallot are pulmonic obstruction and high interventricular septal defect

Fig 13 —Direct resection of an obstructing supraventricular crest. Hypothermia facilitates and adds appreciably to the safety of orthodox surgery in patients with cyanotic heart disease

would be 74° to 79° F (23 3° to 26 1° C) McQuiston[3] and Potts[4] have already reported this use of hypothermia although not at such low levels

B As a means of permitting direct surgical procedures upon the great blood vessels which involve interrupting the circulation to vital centers for prolonged periods of time The optimum temperature range would probably be 70° to 76° F (21 1° to 24 4° C)

C As a means of performing open intracardiac surgery within the chambers of the right heart under direct vision Intra-arterial transfusion and operating under a level of Ringer solution may significantly aid the recovery

2 Children The same indications just mentioned, however, they are less suitable subjects

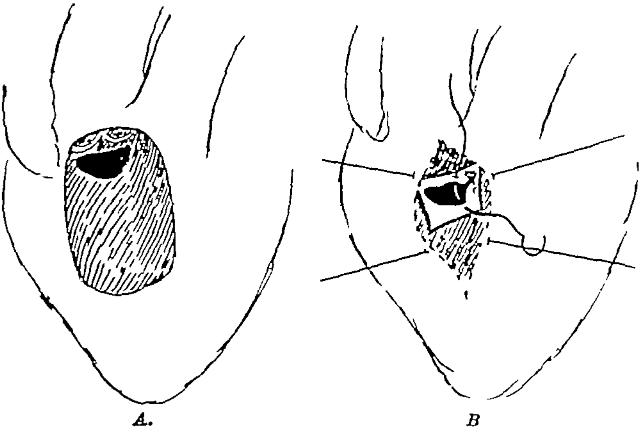


Fig 14 —*A*, Typical high interventricular septal defect approached through a right ventricular incision as in M A. F *B* Direct suturing of the defect. Use of a free patch of pericardium to reinforce the suture line is desirable

3 Adults The same indications, but even less suitable Body temperature should not be brought below 79° F (26 1° C)

CONTRAINDICATIONS TO HYPOTHERMIA FOR CARDIAC SURGERY

1 Severe myocardial damage

2 Acquired heart disease

3 Left-sided lesions which require an open surgical technique

4 Atrial septal defects, since safe and effective closed techniques (atrio-septo-pexy, and polythene bridging by use of a well) now exist Opening the right atrium in the presence of an atrial septal defect is tantamount to opening the left atrium with its inherent risk of peripheral arterial air embolism (Fig 10)

SUMMARY

1 By the use of hypothermia we can safely interrupt the entire circulation for a period of time long enough to open the chambers of the right side of the heart and to perform direct intracardiac surgery

C   *D*

Fig 14—*C* Application of the pericardial patch. *D* Suturing of the defect.

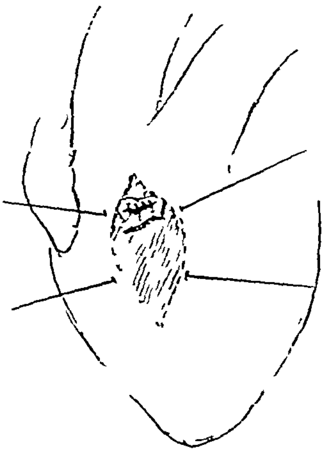


Fig 14*E*—Defect closed

2 The present risk of arterial air embolism presently interdicts opening the left side of the heart and precludes safe use of an open technique for repair of large septal defects

Unfortunately, at the present stage of developments we can only categorically establish the value of hypothermia as a valuable adjunct in the treatment of very cyanotic individuals with congenital heart disease

We hope and believe that the case of M A F points the way to the general application of hypothermia and direct suturing to small interventricular septal defects by the open technique (Fig 11)

A logical extension of the consideration of these two probable uses would suggest the future simultaneous correction of both the pulmonic obstruction and the high interventricular septal defect (with an overriding aorta) in selected cases of tetralogy of Fallot It is only by such a combined program that we can hope to restore the defective hearts of these unfortunate individuals to an essentially normal state (Figs 12 to 14)

CONCLUSIONS

1 Hypothermia is presently of little value in acquired cardiac lesions and in lesions of the left side of the heart

2 Hypothermia is dangerous in adults since the myocardium may become fatally depressed

3 Hypothermia and an open technique are dangerous in treating large septal defects because of the likelihood of air embolism

4 Hypothermia is essentially useful in small children with congenital heart disease involving the right side

5 Hypothermia greatly enhances the chance of recovery as an adjunct in the orthodox surgical treatment of very cyanotic children

6 Hypothermia permits total interruption of the circulation for relatively long periods with complete recovery

7 Hypothermia and open surgery are probably essential for the correction of ventricular septal defects

8 Combining the success in the treatment of cyanotic lesions and that of interventricular septal defects one is led to the idea and hope of complete correction of the essential lesions existing in cases of tetralogy of Fallot

9 Progressive improvements in technique and increased familiarity with hypothermia may eventually lead to its extensive use in permitting open intracardiac surgery for many conditions now treated by closed techniques at normal temperatures

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DISCUSSION

DR F J LEWIS, Minneapolis—I wish to thank the Association for the privilege of discussing Dr Bailey's excellent presentation At the University of Minnesota much of our experience with hypothermia, I am gratified to find, has been somewhat similar to Dr Bailey's We too have planned to use hypothermia both experimentally and in human beings largely to treat defects in which an open procedure would seem to be the essential or, at least, the most desirable method Hence, we have been concerned primarily with auricular and ventricular septal defects

In experimental animals, after some experience was gained, it has been relatively easy to make and, at a later operation, close large auricular septal defects We have used a simple closure technique with a continuous silk stitch and no grafts Coronary air embolism is avoided by outflow occlusion of the heart, plus rapid filling of the left chambers of the heart with saline solution at the time of right atrial closure The problem of ventricular septal defects has, in our hands, been considerably more complicated With hypothermia it is possible to produce ventricular septal defects experimentally, and close them, especially if the septal defects are made in the lower part of the ventricular septum However, the high ventricular septal defects, one of which has been so brilliantly dealt with by Dr Bailey, are, as most of us know, much more different to approach, for they are hidden by the tricuspid valve and intimately associated with the aortic and mitral valves as well Hypothermia, however, does provide a method for producing such defects in dogs, a procedure that I feel is essential before we can take the next step of advocating its usage in human beings

Whether hypothermia does establish itself ultimately as the best method of dealing with some of these intracardiac defects or not, it is, I think, at the present time a very adequate way of producing and closing a large number of intracardiac defects experimentally, utilizing what is essentially a simple technique We find that an effective way to cool animals which have an arteriovenous fistula has been advocated by Boerema, the blood is pumped from the dog's artery out through refrigerated coils and back into its vein It is possible with very little danger to reduce the dog's body temperature to 25° C within thirty minutes and proceed with an intracardiac operation Following this the dog can be rewarmed rapidly in hot water or by immersing these coils in hot water, and the whole technique in the experimental laboratory can be completed in a relatively short time

To date we have used hypothermia in the treatment of three patients with simple atrial septal defects There was one death, a 46 year old woman in congestive heart failure who, interestingly enough, developed an idioventricular rhythm with complete sino atrial heart block during hypothermia She did not recover from this conduction defect and despite the fact that the immediate clinical condition was excellent, the patient died suddenly and unexpectedly on the third postoperative day

DR SAMUEL KAPLAN, Cincinnati—Earlier this afternoon Dr Helmsworth mentioned our experimental observations with hypothermia during complete by pass of the heart It is well known that the young of most species tolerate a lower body temperature better than the fully grown adult of the same species Therefore we extended our studies to hypothermia in newborn puppies and were able to reduce the rectal temperatures to 59° F or 15° C by placing the puppies in ice water At this temperature the heart rate was reduced and we were able to confirm that there was marked reduction in the cardiac output With this experimental background it appeared reasonable to use hypothermia to reduce or abolish hypoxia during the diagnostic study and surgical treatment of congenital cardiovascular anomalies in infants and children It is stressed that this aid was only in desperately ill infants in whom hypoxia was evident

To date, twenty two patients between the ages of 18 days and 4 years have been subjected to hypothermia by surrounding the patient with polyethylene bags containing cracked ice In the majority of patients the rectal temperature was reduced to 75° F or 24° C It took about twenty to thirty minutes to reduce the rectal temperature from the normal to 75° F where it was maintained during the diagnostic study or operative procedure The patients were rewarmed by placing them in a tub of water at 104° F or by surrounding them with hot water bottles During the hypothermic state the pulse and respiratory rates fell with the temperature It is difficult to estimate the optimum temperature for surgical procedures in these desperately ill infants The best guide has been the heart rate When it reaches about 80 to 100 per minute, we believe the optimal temperature has been achieved. Further lowering of the rectal temperature may be associated with arrhythmias, especially heart block, which is preceded by prolongation of electrical systole The placing of ice close to the skin has not produced any irreversible skin changes

It has been said that hypothermia may be a narcotic agent in itself, although it is true that the amount of anesthetic agent required during the cooled state is small, we have repeatedly noted that the infants will cry and move at a temperature of 75° F We have concluded that in infants and young children it is possible to reduce the body temperature to levels described without any harmful effects directly attributable to the hypothermic state The object of hypothermia was to improve the physiologic state of the cardiovascular system because of reduction of general metabolism

DR WILLIAM H. MULLER, Los Angeles—I certainly enjoyed Dr Bailey's very interesting presentation At the U C L A Medical Center we also have been interested in producing hypothermia in certain patients with congenital heart disease who are undergoing cardiovascular operation Our interest arose because we had two untoward experiences during which irreversible central nervous system damage occurred and the patients died after the procedure

Following the work of McQuiston and Potts, Bigelow, and others, we decided to try to lower the temperature slightly, or at least not allow it to rise during the procedure Since there appeared to be certain advantages to actually reducing the temperature, we have used hypothermia during the past fourteen *months* in twenty five selected patients who had congenital heart disease All were children, whose ages ranged from a few days to 17 years Most of these patients were severely cyanotic or were in cardiac failure

The method we have used is very similar to that mentioned by Dr Kaplan, that is, the patient was placed on polyethylene bags filled with crushed ice after the anesthetic was begun The rate of lowering depends on the size of the patient, but the desired temperature can usually be reached within from forty five to ninety minutes In most instances we have reduced the temperature to approximately 24° or 26° C However, in two patients who had transposition of the aorta and pulmonary artery, and in whom we partially transposed the cardiac venous return in a manner very similar to that used by Dr Lillehei and Dr Varco we lowered the temperature even more, 21 5° C in one and 19 5° C in the other

Most of the patients have been followed with the electroencephalograph during the operation and it showed greater changes in control patients than in those whose temperature had been lowered. It was felt that these changes were the result of having to use more anesthesia in the control patients The electrocardiogram shows slowing of the pulse and prolongation of the PR interval and the QRS complex However, ventricular fibrillation, which has been noted in dogs in which the temperature has been lowered, has not developed in any of our patients On the contrary, we feel that there have been fewer serious arrhythmias than would have occurred if cooling had not been used. The blood pressure usually remains the same but may drop slightly We have found no definite point at which the breathing ceases spontaneously In some patients it has ceased at approximately 27° or 28° C However, one patient whose temperature was *lowered to 19°* or 19 5° C still breathed spontaneously We have found that the arterial oxygen saturation in some cyanotic patients may rise considerably as a result of cooling alone In one of the *patients* who had arterial transposition the saturation rose *from* 7 8 *to* 19 7 volumes per cent, just as the result of cooling

We are at present, studying the electrolyte changes and the changes in blood clotting and blood constituents, but do not yet have sufficient data to draw conclusions We raise the temperature in these patients by means of an electric blanket over a period of from one to three hours The blanket is removed when the temperature reaches about 35° C, and it usually returns to *normal* in two or three hours We have had no difficulty with a compensatory hyperthermia We have controlled shivering during this period by one of the curare like drugs, the anesthesia having been discontinued We have had no complications directly attributable to *the* hypothermia, *and we feel that* hypothermia certainly prolongs the operating time reduces arrhythmias, and we think we have been able to get away with many procedures *that* would have been impossible otherwise

Dr Holman asked what success we had in the patients with transposition of the aorta and pulmonary artery We have been able to transpose the superior vena cava and superior pulmonary *vein in two* out of six patients upon whom we attempted it Most of these patients were only a few days or a few *months old*

DR CONRAD R LAM, Detroit—I should like to *congratulate* these pioneers who are working on the use of hypothermia and *to* discuss one of the complications which has been mentioned and which resulted in the death of one of Dr Bailey s patients I refer to the condition called coronary air embolism *Some* work we have done will be reported at another meeting by my associate Dr *Geoghegan, but I* think it is so important *that it* should be *mentioned* here *It* is *possible* to administer a uniformly fatal dose of air, which is 1 5 c c *per kilo to* a dog and to *reverse this* in practically 100 per cent of the dogs A little reasoning will assure us that a bubble of air cannot possibly be an embolus It can pass through the capillary bed and we have demonstrated that such air can be collected in the coronary sinus When the *heart* is failing from coronary air embolism and the bubbles in the vessels are *visible*, the aorta should be clamped and manual systole applied This maneuver provides an adequate pressure in the coronary arteries so that the air is forced out and the cardiac musculature assumes a normal color Obviously, before doing this, the balance of the air in the ventricle should be removed by aspiration, otherwise there will be repetition of the coronary embolism Resuscitation may be complicated by ventricular fibrillation, but the application of the electrical defibrillator will restore normal rhythm Presumably, any air which has gone to the cerebral vessels would be forced out into the venous system also

DR ADRIAN LAMBERT, JR, New York—I am impressed with this work and I would like to ask one or two questions, possibly because it is not quite clear to me what procedure Dr Bailey has used I should like to ask—and this may be redundant in that he may have answered it—whether he has been able to interrupt the arterial circulation to the head without getting permanent changes as a result of this interruption? Second, at what time interval will permanent changes in the brain develop after interrupting the return flow of blood from the head under conditions of hypothermia?

DR BAILEY (Closing)—I had no idea there was so much cooling going on I believe that Dr Lewis and Dr Varco were the first to successfully close an atrial septal defect by an open technique under hypothermia It is quite easy, of course, to make and close interatrial defects in dogs Usually air embolism is not a problem in experimentally created defects, and that is what probably misled us in human beings However, it is different when you have one of these huge low defects such as a persistent ostium primum At least our first patient did not do well by this open technique

I do not know whether I brought out that adult patients do not do very well Those with acquired heart disease such as aortic insufficiency and mitral insufficiency, and one adult with an auricular septal defect of this type, who was not operated on by an open technique but really by an extension of atrio septo pexy, all showed serious difficulty before the definitive surgery was even begun One had ventricular fibrillation before that stage, and put us to the problem of trying to resuscitate the heart even while trying to correct the definitive defect We are quite sure that adults with heart disease of an organic type, particularly of an acquired type, do not tolerate hypothermia very well

CASE REPORT

Actually, it was amazing how easily the defect could be closed in this child with the ventricular septal defect The tricuspid valve was available, but it was not necessary to include it in the sutures as the edges of the defect came together very well I think these high septal defects ordinarily are not associated with much lack of tissue It is just a separation of the two edges and they can be sutured rather easily

Dr Kaplan has reported on Dr Helmsworth's experience He has really operated on a lot of people under hypothermia I understand their patients were mainly children and I suppose they have avoided some of the problems we undertook Certainly these desperately ill cyanotic patients do very well with conventional therapy with hypothermia We have not found any constant temperature at which heart block develops, sometimes it develops at rather higher temperatures than would be expected This is transient unless you actually pick up the atrioventricular conduction bundle with a suture, which can be done deliberately in animals but should be avoidable in human beings because it is characteristically located caudad to the ostium of the coronary sinus I believe we should not have too much trouble with heart block

Dr Muller also has a tremendous series Again I understand that it is largely composed of small children, many of them severely cyanotic I am interested in the method that both he and Dr Kaplan are using to cool these individuals, although it had seemed to us that the blanket was just about as good for an infant as for an adult I am a little amazed that he has not had more trouble with ventricular fibrillation, because in our thirteen cases we had ventricular fibrillation in six. Two of them recovered with proper therapy, but they certainly had it, and I would imagine that this would occur in Dr Muller's series too I do not know whether there was a difference in the type of surgery performed Perhaps more of his was extracardiac surgery All of our operations were intracardiac except in the transposition cases I am not clear as to whether any of his patients were subjected to complete interruption of the circulation, which might be the reason for the difference in our experiences

Certainly the arterial oxygen saturation does rise with cooling in these patients, and they become visibly pink whereas they have been perhaps almost black before the induction of hypothermia I am quite certain that the method of Dr Varco and the method Dr Muller is using for the transposition of the great arteries, are sound I am convinced that one cannot safely transpose the great arteries with any hope of eventual cure, so the only logical answer is to transpose the veins, since the right ventricle will probably be able to compete forever with the higher pressures of the aorta

I am very much interested in Dr Lam's report on the correction of coronary air embolism, because that certainly is something about which we should learn Actually we have tried vigorous massaging of the heart However, even in dogs we have not always been able to get the heartbeat back, in the two patients in our series in whom this occurred we certainly were not able to restore normal contractions They did fibrillate and the fibrillation was persistent

I am a little confused by Dr Lambert's questions Can we completely interrupt the arterial circulation to the brain without damage to the brain, and for how long? I suppose for twenty minutes or for whatever time you interrupt the entire circulation I imagine he means at hypothermic levels We have not specifically interrupted the cerebral circulation in either animals or human beings, but I would suppose that the interruption to the cerebral circulation would be nearly complete within a couple of minutes of clamping the venae cavae, and would last until the general circulation was restored. We have *not investigated* specifically either the venous drainage of the brain or the arterial supply to the brain, but have been able to use prolonged periods of obstruction of circulation in dogs at very low temperatures (16° C), the maximum being around forty minutes without subsequent brain damage that we could detect I believe that by perfusion of the aorta by the technique described, the period of vena caval obstruction could be significantly increased to perhaps an hour

THE MANAGEMENT OF THE DANGEROUSLY TORN AURICLE

WILLIAM K. SWANN, M.D. (BY INVITATION), THOMAS L. LOMASNEY, M.D.
(BY INVITATION), AND JORGE RODRIGUEZ ARROYO, M.D. (BY INVITATION)
KNOXVILLE, TENN.

THE UTILIZATION of the left auricular appendage as an avenue of approach to the diseased mitral valve was first done by Souttar[1] and later by Bailey[2] and Harken.[3] It has now been widely adopted in the treatment of mitral stenosis.

The operative procedure has been fairly well standardized and is described elsewhere.[4] The technique is relatively simple and the procedure is generally a safe one.

However, there are certain normal and pathologic variations in the auricle and its appendage which may render the procedure extremely hazardous. The auricular appendage may be so small that it does not easily permit introduction of the operative finger after amputation or wide opening of the appendage. This will require a lower and more unsafe application of the auricular clamp to the wall of the auricle itself. In the presence of a greatly enlarged auricle or an eccentric location of the mitral orifice, or both, manipulation by the operative finger either with or without a cutting instrument may create exceptional pressure or torsion at the site of the entrance into the auricle. The usually friable auricular tissue may become even more surgically unacceptable in the presence of adhesive pericarditis. It has been necessary to decorticate the auricle in three of our patients in whom this condition was found.

Any one or a combination of these factors may result in a tear in the auricle, and this tear may readily extend below the previously applied purse string.

The operator may or may not recognize when the tear has occurred. He may feel a relaxation or "giving-way" of the auricular wall about the finger; there may or may not be blood loss about the finger at this time. The operator should be prepared to deal with this tear of the auricular wall which is often simply handled by a lower application of the clamp as he withdraws the operative finger. If there is still leakage of blood below the reapplied clamp, a second clamp may be applied below the first one. A nesting group of clamps has been described for this purpose by Harken.[5] It is then a simple matter to remove the proximal clamps and oversew the torn auricle. There are, however, several dangers in the use of this method which are apparent when one considers the anatomic relations of the auricular appendage.

Read at the Thirty-third Annual Meeting of The American Association for Thoracic Surgery, San Francisco, Calif., March 27, 28, and 30, 1953.

SURGICAL ANATOMY OF THE AURICULAR APPENDAGES

The importance of the anatomy of the auricular appendages has been emphasized for us after our experience with two patients undergoing intracardiac surgery in whom a tear of the auricle was produced. We feel that the original descriptions of this anatomy are not entirely adequate for present purposes. The following additions are based on dissections of twenty-four autopsy specimens.

The auricular appendages are the anterior prolongations of the auricles. They embrace, so to speak, the root of the great vessels, the right appendage bending around the aorta and the left around the pulmonary artery. They are both hollow and their darker color distinguishes them from the auricles proper.

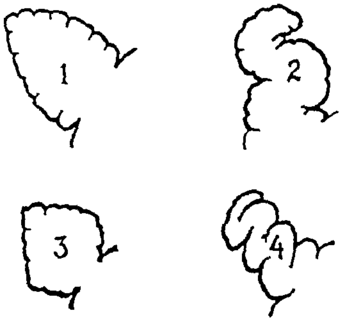


Fig. 1.—Variation in shape of the auricular appendages.

There are four usual shapes[6] (Fig. 1).

(1) Triangular
(2) S shaped
(3) Rhomboidal
(4) Vermicular

On the left side the first two shapes are the most frequently found, the last two being found only occasionally. The right side is more constant, being almost always triangular.

The dimensions are variable but, in general, we can say that the left auricular appendage is longer and narrower than the right, and it presents a definite stricture at its base which is not found on the right side. Its length averages 4.5 cm. but it may vary from 2.5 cm. to 6.5 cm. The width varies from 1 cm. to 2.5 cm.[6]

The right appendage does not present any distinct line of demarcation from the auricle. It averages approximately 3.5 cm. in length, the width averages 2.5 cm.

The left auricular appendage is superimposed over the internal portion of the coronary sulcus and the superior portion of the interventricular sulcus. The appendage is separated from a constant vascular triangle by a layer of fatty tissue. This triangle is formed on two sides by the two branches of the left coronary artery—(1) the anterior descending branch, and (2) the circumflex branch—which meet the great cardiac vein on the third side of the triangle (Fig 2) Some of our dissections revealed two triangles due to a trifurcation of the left coronary artery (Fig 3)

The right appendage covers the internal portion of the right coronary sulcus, overlapping it slightly It is separated from the right coronary artery by fatty tissue

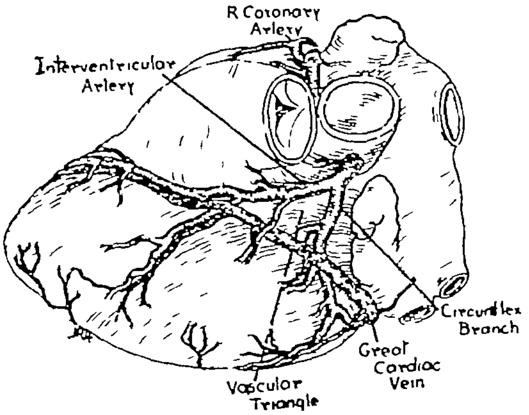


Fig 2

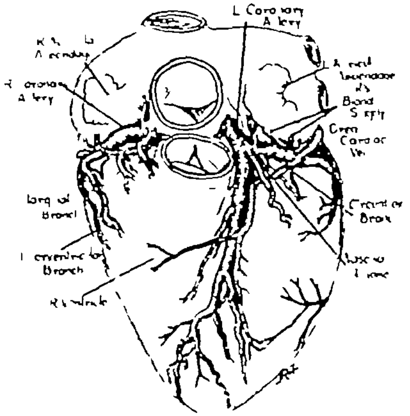


Fig 3

Fig 2—Vascular triangle in close proximity to left auricular appendage

Fig 3—Variation of the vascular triangle caused by a trifurcation of left coronary artery

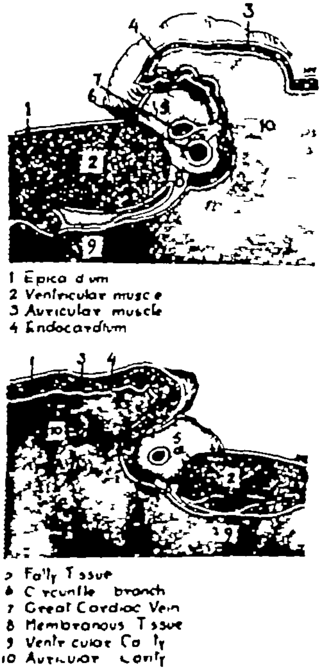


Fig 4—Cross section reveals a part of the auricular wall is without epicardium and more susceptible to tearing or extension of a tear

The blood supply of the appendage is provided by two branches of the circumflex artery although sometimes only one branch is present The veins are tributaries of the great cardiac vein. These vessels help to sustain the appendage in its position against the coronary sulcus since at the point where they reach the appendage, the epicardium is deflected and this provides the basis for dividing the appendage in two portions One of these portions is covered by epicardium and the other is not The latter area is in direct contact with the fatty covering of the coronary vessels in the coronary sulcus (Fig 4)

The right appendage has no direct blood supply from the large vessels This appendage is nourished by secondary divisions of the auricular vessels which arise from the right coronary artery One of our specimens showed a vein of good size emptying in the base of the appendage The right side presents the same two portions as the left one covered by epicardium and the other uncovered.

The cavities of both appendages are a direct continuation of the auricular cavities but there is a case mentioned by Blalock[7] in which the appendicular cavity did not exist

SURGICAL IMPLICATIONS

1 The stricture which is constant in the left side makes the passage of the finger through this appendage more difficult Therefore a tear is more likely on the left side than on the right where there is no such stricture

2 The tear is usually toward the coronary sulcus because of the direction of the pressure of the finger

3 The portion of the appendage namely the base which is not covered by epicardium is less resistant to tear

4. In cases where the auricular appendages are too small to permit safe passage of the finger an alternate approach must be used

5 Due to the close relation of the left auricular appendage to the coronary artery and its branches and the great cardiac vein care must be exercised to avoid suturing these vessels in case of tear of the left auricular appendage Bailey[6] has reported a fatality when he divided a branch of the coronary artery from within the heart while using a guillotine knife

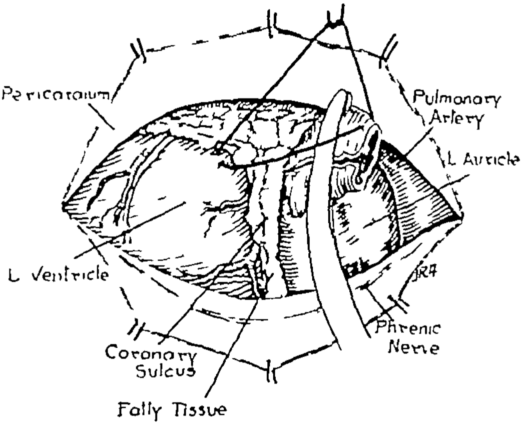
We have had occasion to manage dangerous auricular tears in two of our patients in our relatively small series of forty operative cases We believe that a dangerously torn auricle can be repaired and the patient salvaged by attention to certain details First it is imperative to arrest hemorrhage from the auricle without damage to the coronary vessels This entails a safe application of a clamp or a simple occlusion or compression of the opening by the hand of the operator Second preparation is then made to replace massive blood loss should it occur We have used intra aortic transfusion under pressure for this purpose A suitable instrument should be on hand to clamp the descending aorta should this be necessary as an additional measure to insure the blood supply to the brain Third the auricular tear should be sutured without haste and with good visualization of suture placement

CASE REPORT

Mrs B D, a 39 year old housewife, was admitted to Saint Mary's Memorial Hospital, Knoxville, Tenn, on July 1, 1952, with a complaint of dyspnea on exertion of three years' duration She had become completely disabled for an entire year prior to this time There was a past history of rheumatic fever in 1937

Physical examination revealed the presence of ascites, ankle edema, and auricular fibrillation A large pulmonary artery was observed at fluoroscopy but there was no enlargement of the left ventricle or of the left auricle The over all cardiac size was not appreciably increased The auscultatory findings were consistent with a diagnosis of "pure mitral stenosis" Intensive medical treatment* resulted in loss of the edema and ascites, but attempts at converting the fibrillation were unsuccessful since the patient could not tolerate quinidine

Fig 5



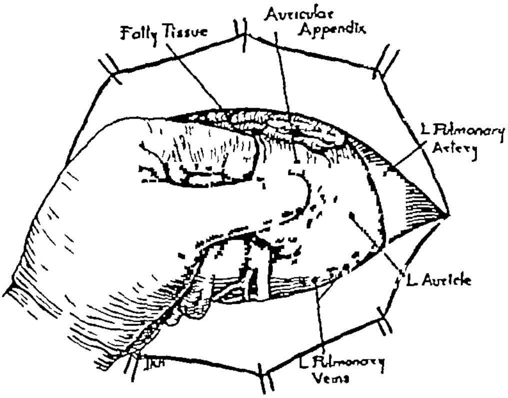


Fig 6

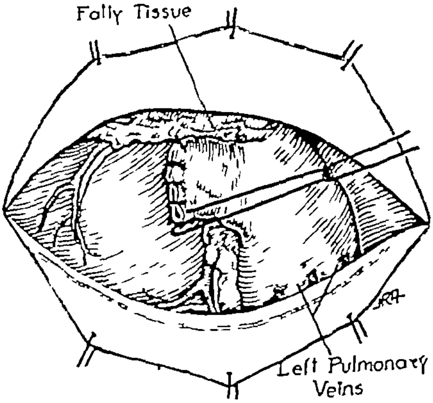


Fig 7

Fig 5—Tear in appendage extending to coronary sulcus

Fig 6—Torn auricle occluded with two fingers and gentle compression of auricular wall against the ventricle

Fig 7—Suture of torn appendage to ventricular muscle over the coronary sulcus

Surgical correction of the mitral lesion was undertaken on Aug 20, 1952 Exploration of the mitral valve through the usual approach revealed an extremely tight mitral stenosis (Type 1) but without calcification In the course of producing a finger fracture of the anterolateral commissure, manipulation of the operative finger produced a tear in the small auricular appendage This tear was observed to progress down the side of the appendage on to the wall of the auricle with a small amount of blood loss at this time The blood loss could be prevented by approximating the thumb against the index finger over the area of the tear in the wall of the auricle As the operative finger was withdrawn from the appendage an effort was made to tent up the auricular wall by grasping the appendage between the thumb and the index finger and thus permit a lower application of the clamp In spite of this maneuver when the clamp was closed it was observed that the tear in the auricle extended below the level of application of the clamp (Fig 5) Several reapplications of the clamp were necessary to prevent continued bleeding With the lowest application of the clamp it was observed that the instrument was in contact with the fatty tissue overlying the coronary vessels in the sulcus An attempt was made to oversew the appendage distal to the clamp but in doing so this tissue was partially avulsed, possibly due to repeated applications of the clamp to the friable auricular tissue

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*Directed by Doctor Robert J Brimi

A maneuver was then deliberately adopted which consisted of insertion of two fingers of the left hand back into the auricle as the clamp was removed The wall of the auricle was compressed at the same time against the fingers by the thumb of the left hand This "two fingers in the dike maneuver" resulted in complete arrest of the hemorrhage (Fig 6)

This situation was maintained until the blood previously lost had been replaced through the usual venous routes and preparation was made for rapid replacement of blood in anticipation of its loss during definitive closure of the torn auricle A No 16 needle was introduced into the aorta and suitable arrangements made to give the blood under pressure After a few minutes the patient had completely recovered from the initial blood loss, and it was elected to repair the defect by turning the auricular wall and what remained of the auricular appendage downward over the coronary sulcus and suturing the torn auricle to the ventricular muscle (Fig 7) Interrupted mattress sutures of fine silk on atraumatic needles were used for this purpose The sutures in the ventricular muscle were placed at right angles to the direction of the fibers to prevent avulsion of muscle Because of the low pressure in the auricle, tight sutures or continuous sutures were not necessary for this purpose Care was taken to avoid branches of the coronary artery Active bleeding occurred during this maneuver, but perfect visualization was maintained throughout by adequate suction apparatus and the patient's condition was prevented from further deterioration by giving 700 c c of blood under pressure directly into the aorta After completion of the auricle to ventricle suture the area was covered with a small strip of Gelfoam sponge and the pericardium was sutured snugly over the repair

At the termination of the operation the blood pressure was 70/40 but shortly thereafter was above 100 systolic Thereafter the postoperative course was not particularly remarkable and the patient was discharged home on Sept 12, 1952 At the present time she is able to do light housework without exertional dyspnea

SUMMARY

In a series of forty mitral valve commissurotomies, two instances of hemorrhage from a dangerously torn auricle were encountered One of these cases is described in detail together with a method of managing this emergency

It is emphasized that the surgeon in his haste to arrest hemorrhage from the torn auricle may possibly create an irreversible situation by application of the clamp across the coronary vessels The application of clamps without perfect vision is therefore inadvisable

Blood loss can be controlled by occlusion or compression of the torn auricle with the operative hand while preparations are then made for rapid intra aortic blood replacement before definitive closure of the defect is attempted These tears can then be managed safely under direct vision Dangerous ill advised, and hasty maneuvers are to be avoided

ADDENDUM

Since preparation of this manuscript a similar method for managing this surgical emergency has been described by C P Bailey, H E Bolton, and H P Redondo Ramirez.

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DISCUSSION

DR ROLLINS HANLON, St Louis—I have enjoyed this presentation of Dr Swann and his associates and would like to emphasize one point which we have found important in handling the left auricle Everyone realizes that it is inadvisable to apply a clamp very low down on the auricle, and this is unlikely to occur except in the face of severe bleeding due to a tear On the other hand with a small fibrotic auricle, one may occasionally make an injudicious application of the clamp even in the absence of bleeding

When the clamp on the auricle compresses the coronary artery, the result may be ventricular fibrillation It is helpful to have some warning of the onset of this complication before it is detected by inspection of the heart Drs T G Mudd and J Inkley of the Division of Cardiac Catheterization have pointed out an electrocardiographic sign which has been useful to us in the operating room in detecting incipient ventricular fibrillation We employ a continuous oscilloscopic recording of the cardiac action which is periodically transferred to a recording electrocardiograph

(Slide) This shows the normal activity of the heart before surgery was begun, followed by the defect in the electrocardiogram which indicates impending ventricular tachycardia or fibrillation, namely, the high takeoff of the S T segment When this change is seen, it calls for immediate reapplication of the clamp or a prompt shift in its position As seen in the other parts of the tracing, this initial change in the electrocardiogram went from ventricular tachycardia into ventricular fibrillation

(Slide) In this instance, the heart was defibrillated promptly by simply changing the position of the clamp without the necessity for electrical defibrillation In this tracing, a regular complex can be seen following closely after the ventricular fibrillation although some evidence of injury persists The tracing had reverted to normal, as can be seen, at the end of the operation

By watching closely for this high takeoff of the S T segment during manipulation of the auricle, the surgeon should receive considerable assistance in the avoidance or prompt treatment of ventricular fibrillation

DR SWANN (Closing)—I would like to thank Dr Hanlon for his discussion The manuscript contains an addendum on a similar method of handling auricular tears that has been described by Dr Bailey and his associates since our abstract was submitted

CYSTIC HYGROMA OF THE NECK ARISING AFTER THORACOPLASTY

EMIL ROTHSTEIN M.D ,* AND EDWARD B GALL, M D **
DAYTON, OHIO

CYSTIC hygroma is a benign endothelial-lined multilocular cystic tumor of lymphangitic origin A review[1] of twenty cases of cervical hygroma treated at Johns Hopkins Hospital from 1936 to 1946 was made by Ward and his associates They found that 93 per cent of all hygromas occur in the neck The etiology is unknown but it is surmised that the cystic cavities are formed by a widening of normal lymph spaces In the John Hopkins group fifteen of the twenty were male patients sixteen were noted before the age of 10 years, and sixteen occurred on the left side of the neck. Two of their patients were adults, in one the hygroma started at age 26 and the other at age 41 years

This report deals with the development of cystic hygroma in the neck of a 39-year old man, three months after a thoracoplasty

CASE REPORT

L W , a 39 year old man, had been ill with pulmonary tuberculosis since 1944. An anterior right thoracoplasty (three ribs) was done Feb 14, 1949, an anterior Monaldi drainage on March 8, 1949, and a posterior thoracoplasty (four ribs) on March 16, 1949 The next stage of surgery was delayed because of a chronic draining infection of the posterior thoracoplasty incision

In June, 1949, the patient noted a small swelling in the right supraclavicular region This gradually increased so that by March, 1950, it was approximately 8 cm in diameter (Fig 1) The only symptom was slight discomfort upon swallowing, possibly due to pressure upon the esophagus The swelling was soft and fluctuant There was no tenderness, redness or induration The mass was compressible to some degree but could not be made to disappear by means of pressure It was dull to percussion, no breath sounds or murmurs were audible over it Upon forced expiration with the glottis closed the structure became somewhat more prominent

Upon x ray examination (Fig 2) the mass was seen to be opaque Esophagram and bronchogram both failed to reveal significant findings

The mass was explored (E B G) on June 28, 1950 A cystic mass about the size of a grapefruit was found beneath the subcutaneous tissue, lying below the trapezius muscle superiorly and projecting below the clavicle anteriorly No definite pedicle could be found nor was it in direct communication with any formed lymphatic or other vascular structures It was removed in toto

The cyst was filled with a cloudy white fluid Examination of this fluid revealed 5 per cent protein with 19,100 cells, 100 per cent of which were lymphocytes Smear and culture were negative for tubercle bacilli and other organisms Microscopic examination revealed large cavernous spaces lined with endothelium Some spaces were engorged with red corpuscles the majority were empty The cyst walls were of connective tissue with

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From the Veterans Administration Center Dayton Ohio and the University of Cincinnati College of Medicine, Cincinnati Ohio

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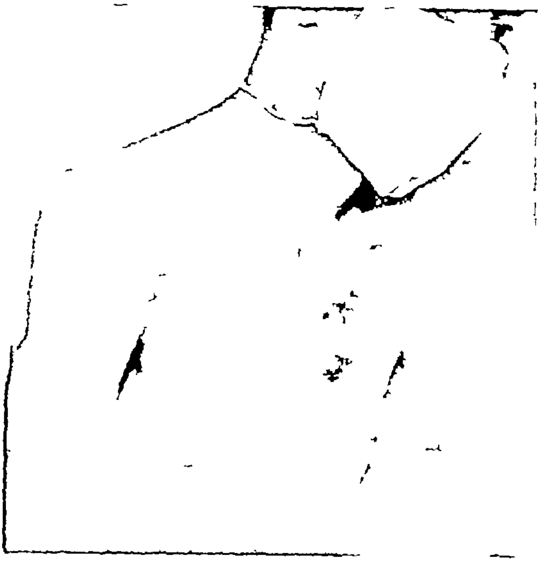

Fig 1.—Cystic hygroma can be seen presenting subcutaneously in the right supraclavicular region

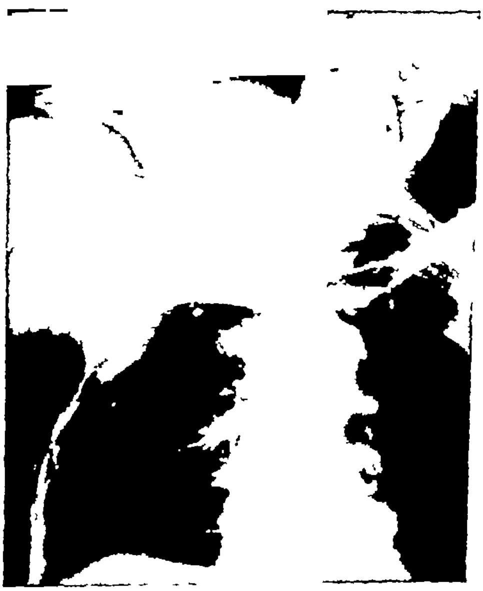

Fig 2.—Roentgenogram revealing radiopaque character of the cystic hygroma

numerous small papilliferous projections extending from the lining These were engorged with lymphocytes and contained lymphatic channels The pathologic diagnosis was hygroma

The postoperative course was uneventful and no recurrence was noted during the following two years

DISCUSSION

Two points of interest are raised by this case The first of these deals with the preoperative differential diagnosis A soft nontender mass arising in the neck after thoracoplasty was a unique experience for us Certain conditions were considered which were unrelated to the previous surgery, such as lymphoma, tuberculous glands, etc, but seemed ruled out by the soft, fluctuant, compressible character of the lesion

Herniation of the lung was considered but was ruled out by the opacity of the lesion upon x-ray examination, by the failure to fill the lesion by means of bronchography, and because of the fact that preoperatively the right upper lobe had appeared totally diseased by consolidation and cavitation

Arteriovenous aneurysm was suggested but was ruled out by the absence of a murmur or thrill and by the fact that the lesion, while compressible, could not be completely obliterated, indicating that the fluid it contained was not in free communication with the vascular system The preoperative diagnosis of hygroma was accurately made based upon the known behavior of this lesion plus the differential diagnostic features mentioned

The second point of interest deals with the possible relationship between the surgical procedure and the development of the hygroma This is a lesion of unknown etiology and has not previously been identified with the postoperative course of thoracic surgery Other cases have been reported, though rarely, in adults of this patient's age Yet we are intrigued by the thought that the anterior and, later posterior right upper thoracic surgery might in some way have affected the anatomy or physiology of the right lymphatic duct so as to give an impetus to the perhaps latent potentialities of hygroma development in this individual

SUMMARY

Approximately three months after right upper anterior and posterior thoracoplasty, a soft cystic tumefaction appeared in the right side of the neck of a 39 year old patient This was removed about one year later and was found to be a cystic hygroma The differential diagnosis and the possibility of a relationship between thoracoplasty and hygroma are briefly discussed

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Announcement

THE AMERICAN ASSOCIATION FOR THORACIC SURGERY

Notice of Annual Meeting

The 34th annual meeting of the American Association for Thoracic Surgery will be held May 3, 4, and 5, 1954, in Montreal, Que., Canada. Headquarters will be at the Sheraton Mount Royal Hotel.

Requests for Hotel Reservations

These should be mailed *directly* to the Reservation Manager, Sheraton Mount Royal Hotel, Montreal, Que., Canada. Please mention this Association, type of accommodation desired, date, and approximate hour of arrival. If accommodations are desired elsewhere, please communicate directly with hotel of your choice.

Thoracic Surgical Forum

After due consideration, the Council has decided to try an experiment by assigning one morning session to a "Thoracic Surgical Forum" for the presentation of short papers on current thoracic research, anatomy, modified surgical techniques, etc. Papers at this session will be limited sharply to ten minutes (including the showing of lantern slides or other illustrative material) with three minutes as the maximum discussion of each paper.

These papers will be published together in one issue of THE JOURNAL OF THORACIC SURGERY. Maximum length 3,000 words without illustrations. If illustrated, an appropriate number of words must be subtracted for each cut used.

Abstracts for Papers

Abstracts for the presentation of papers at the 1954 meeting, including papers before the Forum, must be received on or before January 1, 1954, otherwise they will not be considered by the Program Committee.

Abstracts should be labeled "For Forum" or "For Regular Program."

Five, repeat five, copies of each abstract should be sent to the Secretary of the Association, Dr. Paul C. Samson, 2938 McClure St., Oakland 9, Calif. They should not be sent to the Editor.

The abstracts should contain from 200 to 250 words and accurately reflect the contents of the completed paper.

Applications for Membership

Applications for Associate Membership in the Association must be received by the Membership Committee not later than Jan. 1, 1954, to be considered for action in Montreal. Applications received beyond this deadline will be deferred for consideration until 1955.

Applicants must be sponsored by three Active or Senior Members of the Association. In addition to the sponsoring statement on the application form, the sponsors *must* submit a separate letter concerning the applicant direct to Dr. Lyman H. Brewer, III, Chairman of the Membership Committee, 2010 Wilshire Blvd., Los Angeles, Calif. Completed application forms should likewise be sent to Dr. Brewer. These regulations are at the direction of the Council and were made effective in 1952 at Dallas.

The Journal of Thoracic Surgery

Vol. 27 FEBRUARY, 1954 No. 2

Original Communications

TORSION BALLISTOCARDIOGRAPHY IN CARDIOVASCULAR SURGICAL PATIENTS

C. Frederick Kittle, M.D.* (by invitation), Kurt R. Reissmann, M.D. (by invitation), E. Grey Dimond, M.D. (by invitation), and
Paul W. Schafer, M.D.
Kansas City, Kan.

CONCERTED interest in cardiovascular diseases, undoubtedly aroused by tremendous strides in the diagnosis and surgical treatment of these conditions, has occasioned the exploitation of varied biophysical methods for better understanding of the basic factors in cardiovascular physiology. Ballistocardiography, although recognized and described in 1877 by Gordon,[1] remained a relatively unknown technique until recent years. After interest was stimulated in this subject by the fundamental work of Starr in 1939,[2] numerous investigators have devoted themselves to its study.[3-8] Ballistocardiography is a method of recording body movement caused by the acceleration and deceleration of blood as it is ejected and moved about in blood vessels, and to a certain extent by the *motion* of the heart. Our interest in this field has involved study of the ballistocardiogram in patients subjected to cardiovascular surgery, as recorded by a particular type of apparatus termed the torsion ballistocardiograph. In these patients it has been possible to correlate known anatomic defects and surgical alterations with ballistocardiograms before and after operation. Since this review is based on serial records of the same patient, many problems inherent in the comparison of ballistocardiograms in different patients are eliminated.

METHOD

The most important factors causing the ballistic waves are the acceleration produced by cardiac ejection of blood and its subsequent deceleration in the great vessels and arterioles. Although right and left ventricular con-

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From the Departments of Surgery and Medicine, The University of Kansas Medical Center.

Read at the Thirty-third Annual Meeting of The American Association for Thoracic Surgery, San Francisco, Calif., March 27, 28, and 30, 1953.

*Markle Scholar in medical sciences.

tractions are the primary forces in acceleration of the blood, numerous variables influence deceleration: the dimensions of the aorta, the elasticity of the aorta, the site of deceleration, and arteriolar drainage.[9-13] The final ballistocardiogram is the summation of all these accelerating and decelerating forces. All of these forces are vectors, that is, they are characterized by both direction and amplitude and their direction depends upon the topographic anatomy of the heart and great vessels.

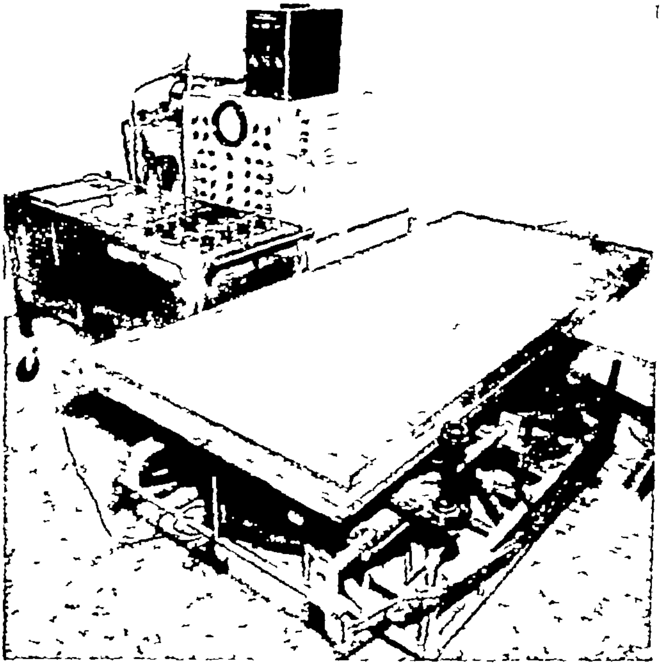

Fig. 1.—The torsion ballistocardiograph. The table is in the foreground while the recording and amplifying devices are seen in the background.

Because these forces are vectors the torsion ballistocardiograph was devised in an attempt to delineate their direction and their origin. The torsion ballistocardiograph consists of a table top supported only by an upright steel bar in its center (Fig. 1). This steel bar because of its torsion elasticity permits circular movements of the table. Forces along axes through the center of rotation cause no displacement of the table. The magnitude of any circular displacement of this table is proportional to the product of the force times its distance from the center of motion (lever arm). When the force acts farther away from the center a proportionally greater displacement is present than when it acts closer. By positioning a patient in relation to the center of motion, reaction forces in various parts of the cardiovascular system can be accentuated or attenuated. By noting the position of the patient where a given ballistic complex is greatest, where it is absent, and where it is reversed, it is possible to predict approximately its anatomic site of origin and its direction of flow. Knowledge of these factors is more important in the study of congenital cardiovascular defects than in other types of cardiovascular disease

The technical details of construction and the physical characteristics of this torsion ballistocardiograph have been presented in previous reports[14-15] The rotational displacement of the table is converted into proportional voltage utilizing condenser plates in a carrier frequency circuit one plate being stationary the other being mounted to the table top The rectified output is amplified by a DC amplifier and recorded by a Sanborn Polyviso machine A frequency response for the table of $\frac{1}{2-f}$ was selected for reasons discussed elsewhere[14-15] This frequency response in the range from 1 to 20 cycles per second was secured by using a table with a natural frequency of 4 cycles per second and supercritically damping it with a piston moving in an oil-filled cylinder Changes in the momentum of inertia of the system with people of different weight or in different positions on the table cause only negligible variations in the frequency response

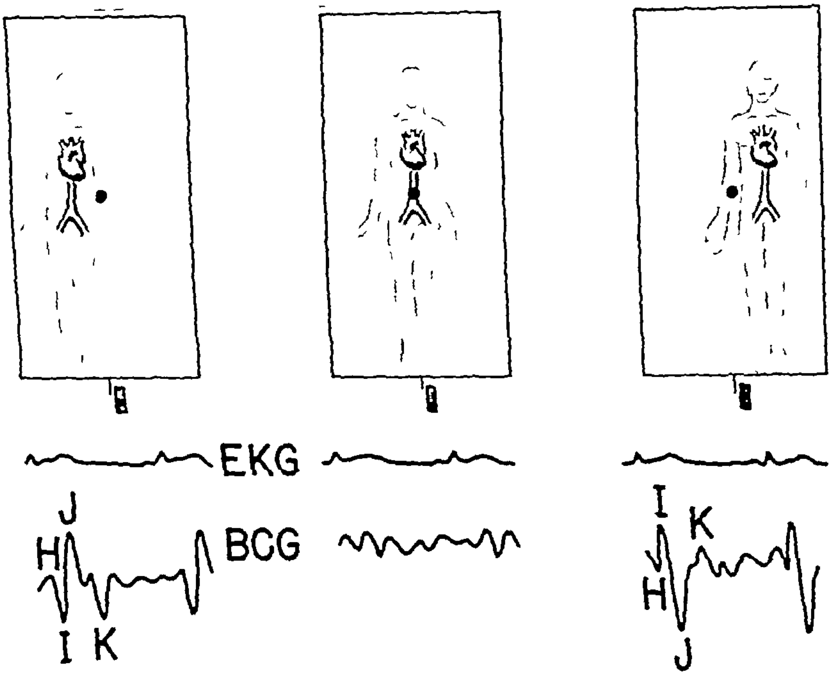

Fig 2—Torsion ballistocardiogram of a patient in various positions on the ballistocardiograph table. In the position on the left-hand side an upper recoil produces a clockwise motion of the table the same motion in the position in the middle produces no motion of the table and in the position on the right hand side of the drawing an upward force causes a counterclockwise rotation Note how the H wave is reversed (as well as the other wave) in direction as the patient changes position in relation to the center of rotation. Transverse forces would produce no appreciable changes in either the left- or right-hand positions on the table The positions on the left and right sides of the table emphasize head-foot forces The normal ballistocardiogram is similar to the one on the left hand side of the table

Standardization of the ballistocardiogram is done by applying a known force to the table end with the patient lying on the table in the selected position To accomplish this, a mass of 1,500 Gm was attached by a spring to the table top and caused to oscillate electrically The recorded amplitude of these sinusoidal table oscillations provides the system calibration

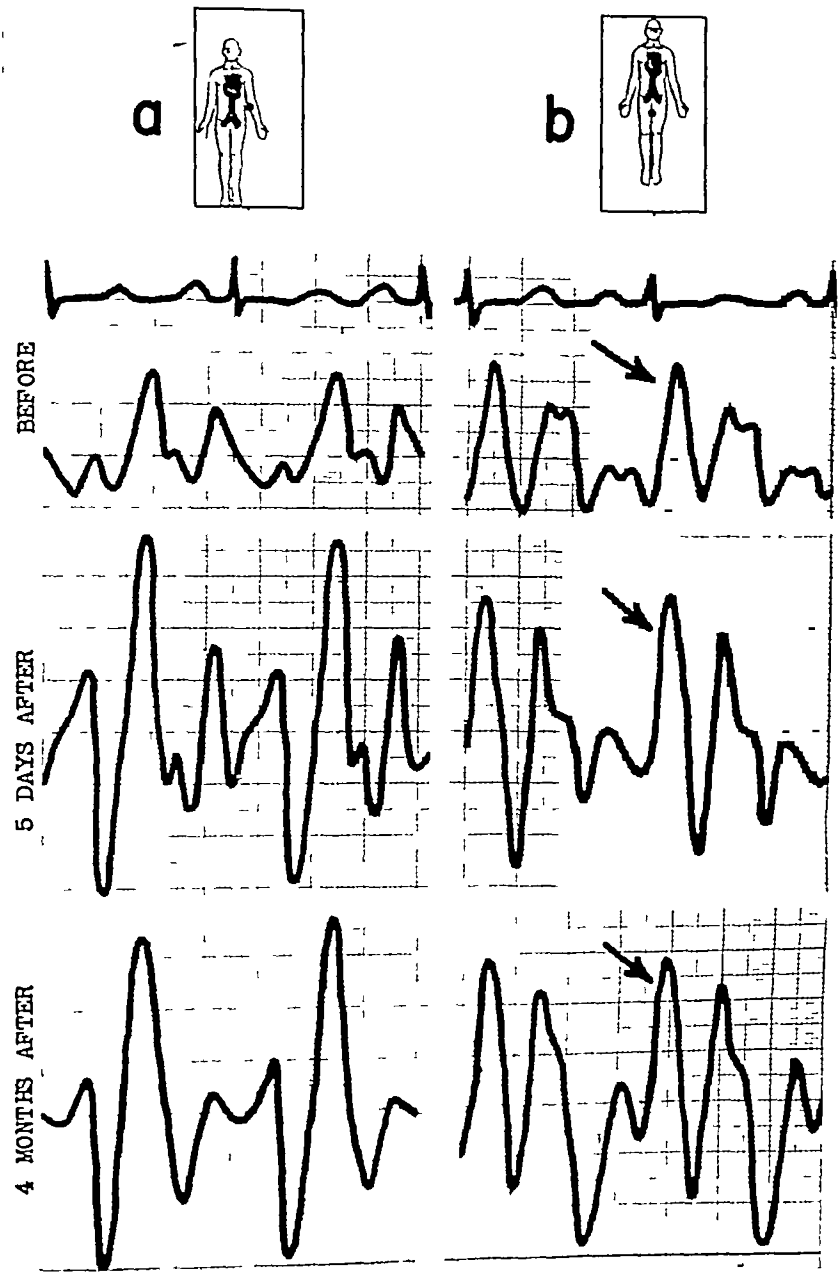

Fig. 3.—Mitral stenosis. Note the comparative increase in the amplitude of the diastolic complexes, particularly with the patient in the position where longitudinal vectors are emphasized (*a*). In the other position (*b*) a prominent wave in early systole (as indicated by the arrow) is seen. The ventricular complex becomes larger following operation; the abnormal wave believed to represent movement of the enlarged left auricle persists.

All records were taken in mid-respiration with the patient lying supine. An upward peak in the ballistocardiogram represents a clockwise rotation of the table top (viewed from above), a downward swing, a counterclockwise rotation. It must be recalled that this is the direction of the recoil force rather than the actual acceleration of the blood, which is directly opposite to the recoil.

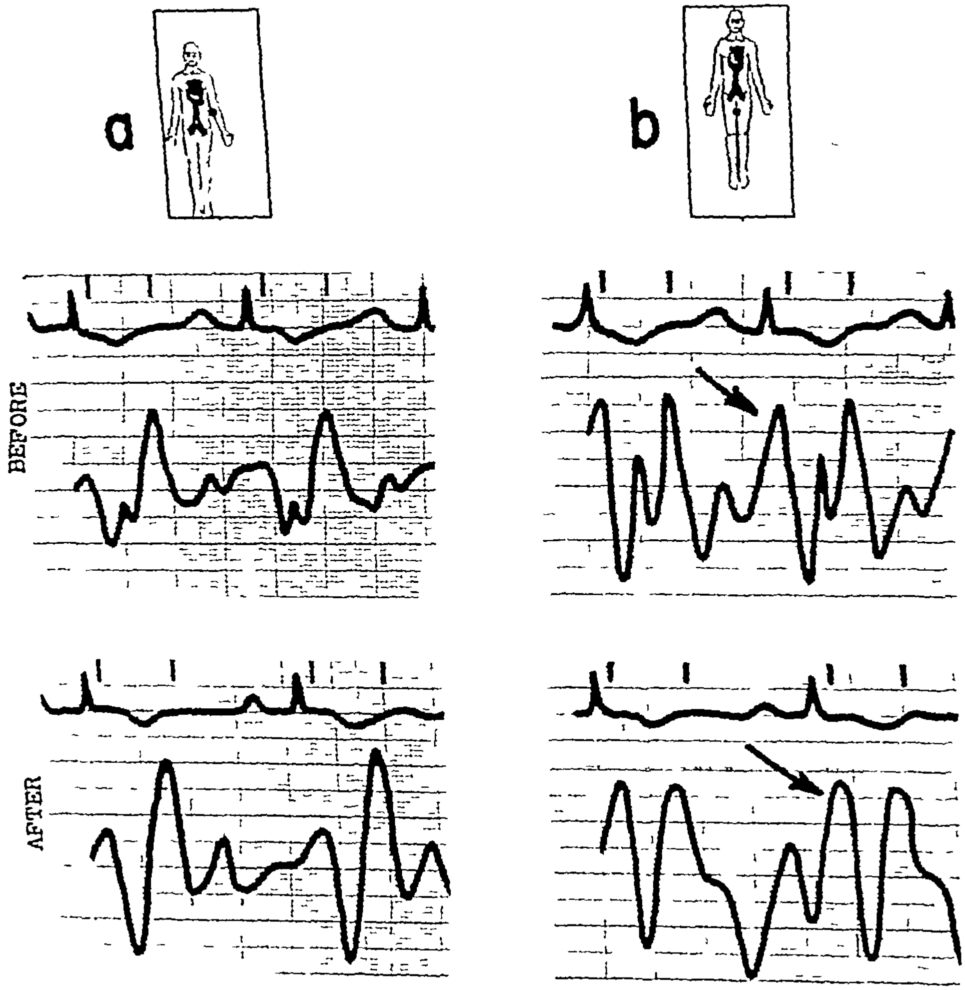

Fig 4.—Mitral stenosis. Changes similar to those seen in Fig 3 are observed.

Simultaneous electrocardiograms and or phonocardiograms were taken to serve as a time reference only.

RESULTS

1 *The Normal Ballistocardiogram*.—Immediately following systolic activity as denoted by the *R* wave of the electrocardiogram or the last portion of the first heart sound is a deflection in the ballistocardiogram termed the

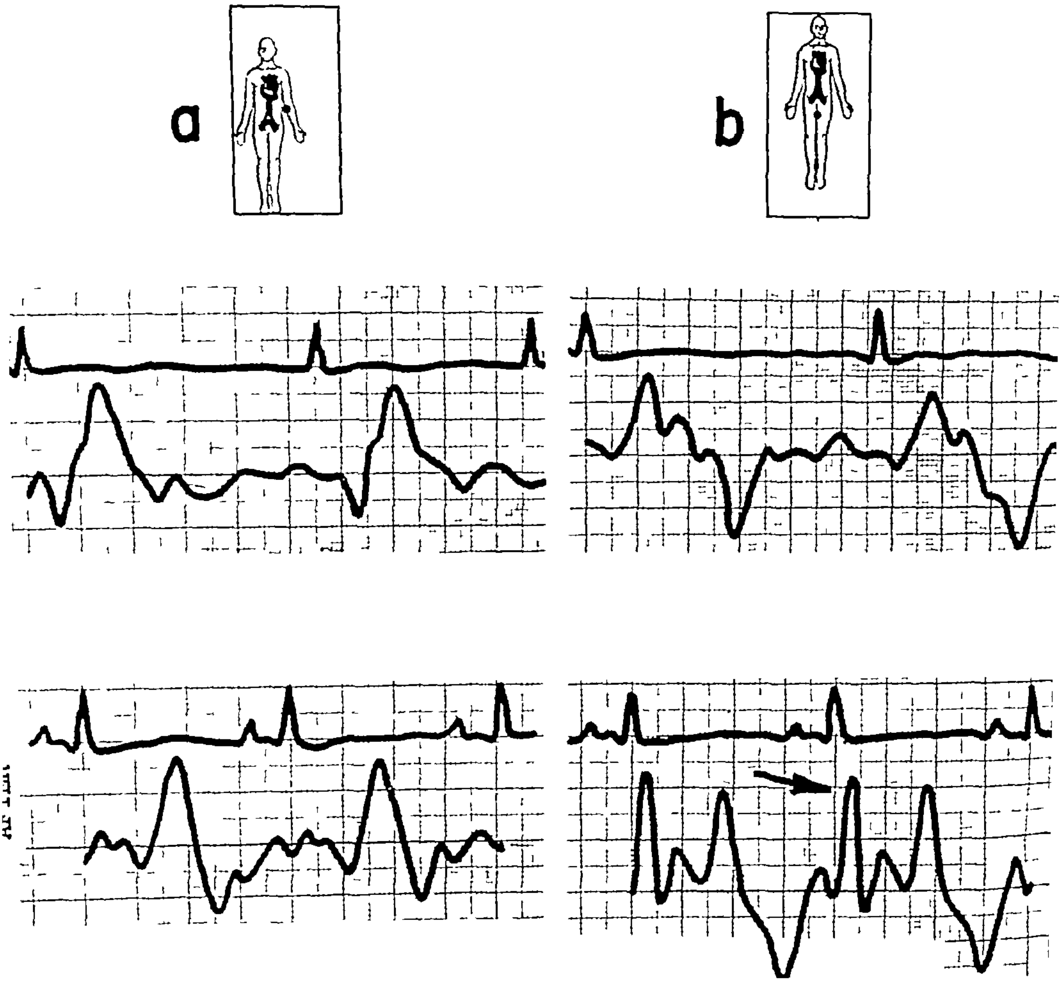

Fig. 5.—Mitral stenosis. Auricular fibrillation preoperatively; normal sinus rhythm postoperatively. Note that the abnormal wave in early systole (see arrow) is present only during normal sinus rhythm.

H wave. This subsequently reverses its direction as the *I* wave, generally deviating below the original base line and occurring roughly simultaneously with the onset of the femoral pulse and slightly before the peak of the carotid pulse wave. The *J* wave is much greater in amplitude and is related temporally to the ascending slope of the femoral pulse and the peaks of the carotid and abdominal aortic pulsations. The last major wave of the systolic complex, the *K* wave, is large and is almost coincident with the second heart sound, the descending portion of the femoral pulse and the dicrotic notch of the carotid pulse wave. Subsequent other waves, designated as *L*, *M*, and *N*, appear to be related to activities during diastole and are not as well defined as the *H*, *I*, *J*, and *K* systolic complexes.[16]

The normal torsion ballistocardiogram and some of the alterations produced by changing the patient's position on the table are illustrated in Fig 2 Here it may be noted that an upward wave on one side of the center of rotation becomes a downward deflection on the other side demonstrating use of the torsion ballistocardiography in determining the site of origin of wave forms

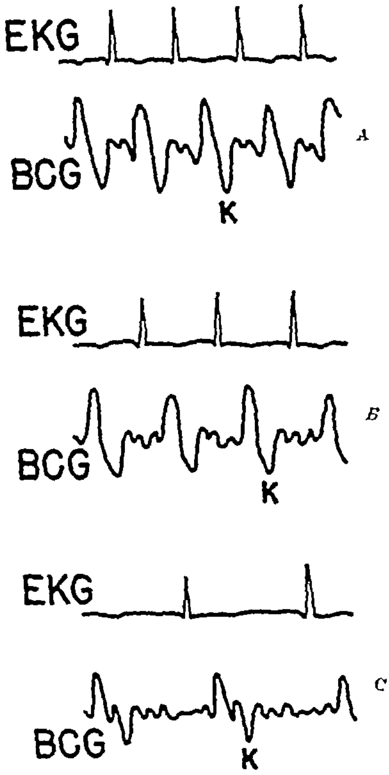

Fig 1 —Acute experimental coarctation produced by progressive occlusion of the thoracic aorta in the dog Ballistocardiograms taken to emphasize longitudinal vectors In *A* the normal tracing is shown in *B* approximately one-third of the lumen is occluded with bowing and deforming of the K wave in *C* the aorta is almost completely obstructed with notching of the K complex Reflex slowing of the heart is noted a compensatory mechanism for the *acute aortic obstruction*

B Mitral Stenosis—Examination of tracings obtained from patients with primarily mitral valvular disease revealed abnormal records with fairly uniform qualitative changes (Figs 3 to 5) It might be anticipated that these lesions would influence the ballistocardiogram by virtue of the altered stroke volume A marked diminution in the entire ventricular complex was found with comparative increase in the diastolic components[1, 16] This is illustrated by the small abnormal I and J waves and their delayed onset Following valvulotomy these waves increased markedly in amplitude no delay was seen in their onset their configuration was normal and the diastolic waves became proportionally smaller Indeed in those cases where a good clinical result was obtained the ballistocardiogram following operation was interpreted as being essentially normal These changes were found in the ballistocardiogram taken in a position where the head-foot forces were accentuated (Figs 3, *a*, 4, *a*, and 5, *a*)

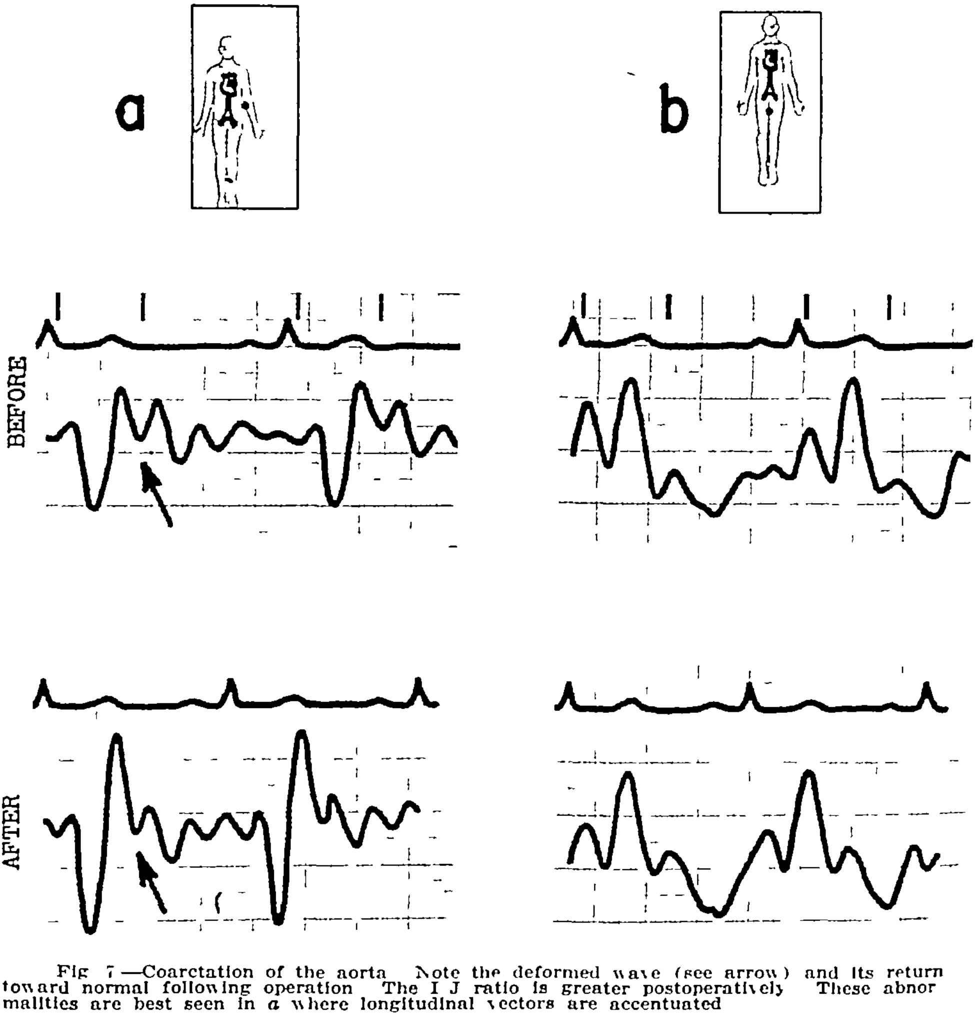

Fig 7 —Coarctation of the aorta Note the deformed wave (see arrow) and its return toward normal following operation The I J ratio is greater postoperatively These abnormalities are best seen in *a* where longitudinal vectors are accentuated

With the patient placed in a position (longitudinal axis of the table through its center) to emphasize transverse vectors, a prominent wave synchronous or slightly after the R wave of the electrocardiogram was noted (Figs 3 *b*, 4, *b*, and 5, *b*) This remained following valvulotomy Its direction indicated a right-to-left reactive force In those patients with mitral stenosis who were fibrillating this wave was not found However, in one patient who was fibrillating initially (Fig 5 *a*) and reverted to a normal sinus rhythm postoperatively, the wave was noted, but only during normal rhythm (Fig 5, *b*) Because of its indicated site of origin and its occurrence during normal sinus rhythm solely, it is believed that this wave emanates from the enlarged left auricle, it probably represents movement of the auricle rather than the blood moved by contraction of the auricle

No essential differences in ballistocardiographic patterns were found between those patients with mitral stenosis and mitral insufficiency, or their combination Most of the patients undergoing mitral valvulotomy had cardiac catheterization preoperatively and postoperatively but only a crude correlation was found between the calculated stroke volume and the amplitude of the ventricular complex of the ballistocardiogram

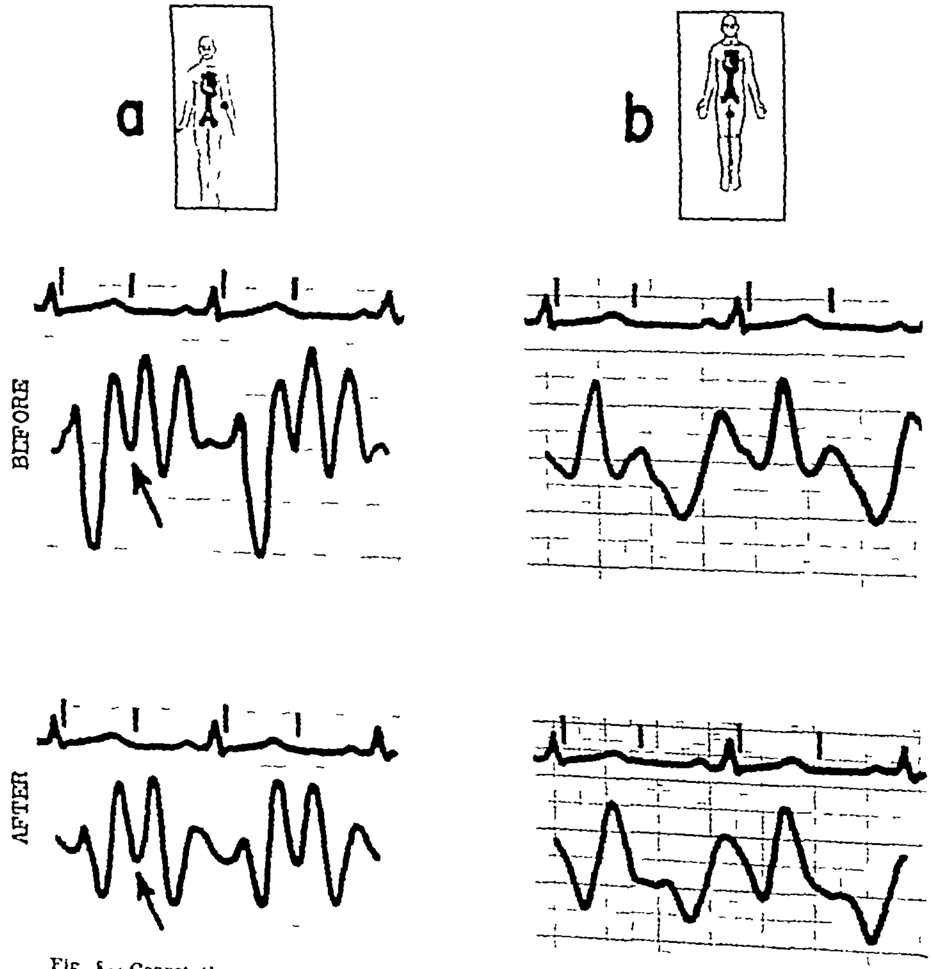

Fig 8—Coarctation of the aorta similar changes as described in Fig 7 but abnormal ballistocardiogram still present following operation. The coarctation could be repaired only by insertion of a homologous aortic graft

C Coarctation of the Aorta—That a distinctive pattern of ballistocardiography is obtained in the patient with coarctation has been appreciated for many years [1, 7] Abnormalities in aortic flow are indicated chiefly by major changes in the K wave and minor abnormalities in other complexes. These deviations are well demonstrated in Fig. 6 which depicts the malforming of the K wave caused by an increasing obstruction to the thoracic aorta in a dog.[22]

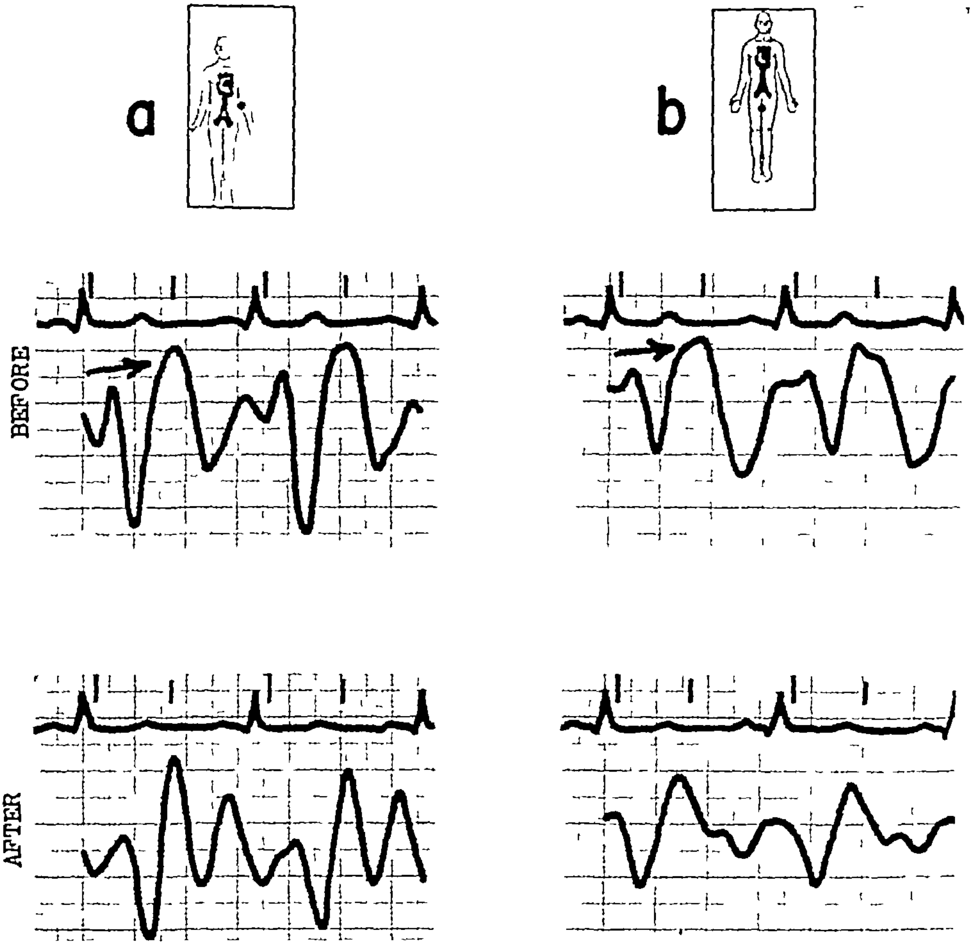

Fig. 9.—Persistent ductus arteriosus. Before operation an abnormal wave (see arrow) is seen in late systole, particularly in *b* where transverse vectors are accentuated. This abnormality disappears after operation.

Coarctation of the aorta is perhaps the best example where ballistocardiography can be used as a diagnostic procedure although even in this condition it is of relatively little practical importance. The changes in the ballistocardiogram in coarctation of the aorta are in the latter part of the ventricular complex and are due to the abrupt narrowing of the aorta with its marked impeding of the blood flow. The alterations are due to a greater than normal flow headward during the first half of systole producing an I wave of longer duration and greater amplitude than normal and a delayed and less accelerated flow footward with a smaller and often delayed J wave with the absence or diminution of the K wave These abnormalities were observed in all our patients with coarctation and were found to be reversed in varying degrees after operation (Figs 7 and 8) The normal ratio of the I J amplitudes is about

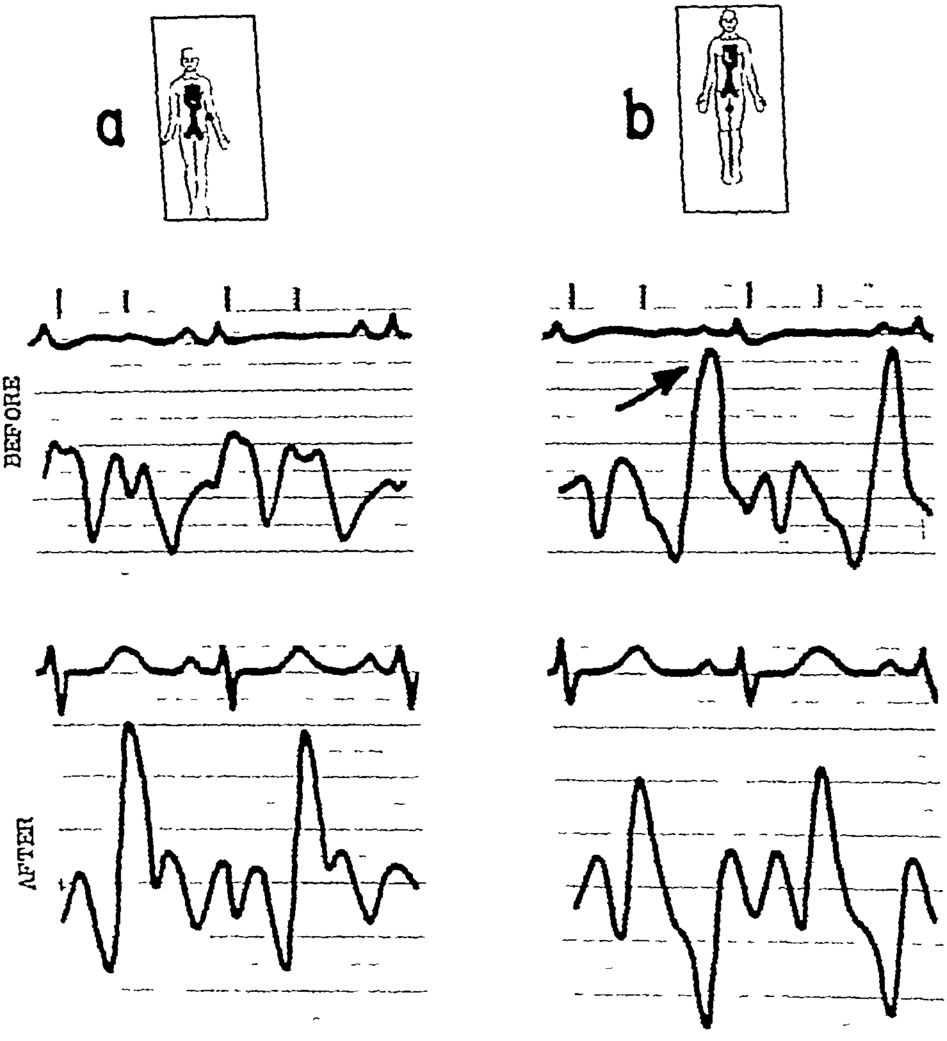

Fig 10—Chronic constrictive pericarditis Attention is directed to the large wave occurring in diastole in the position where transverse vectors are emphasized (see arrow) This disappears after operation as the ballistocardiogram becomes essentially normal.

1 1 2 but in those patients with coarctation it is decreased averaging about 1 0 64 in our series The ratio following operation was found to be about 1 1 The ballistocardiogram thus provides an indication of the amount of blood passing through the aorta and may be of value in assessing this group of patients postoperatively

D Persistent Ductus Arteriosus—It would be expected that in patients with an appreciable amount of blood flow through a ductus arteriosus, a vector could be ascertained pertinent to the ductus Such a wave was noted in the ballistocardiograms of our patients with ductus arteriosus Normally the J wave is terminated at the end of systole and returns to the base line, but in these patients a strong positive wave persisted This was particularly accentuated when the patient was in the transverse position (Fig 9, *b*) Since the wave deviated upward and was most prominent with the patient so placed, it must be a vector acting from right to left with a headward component

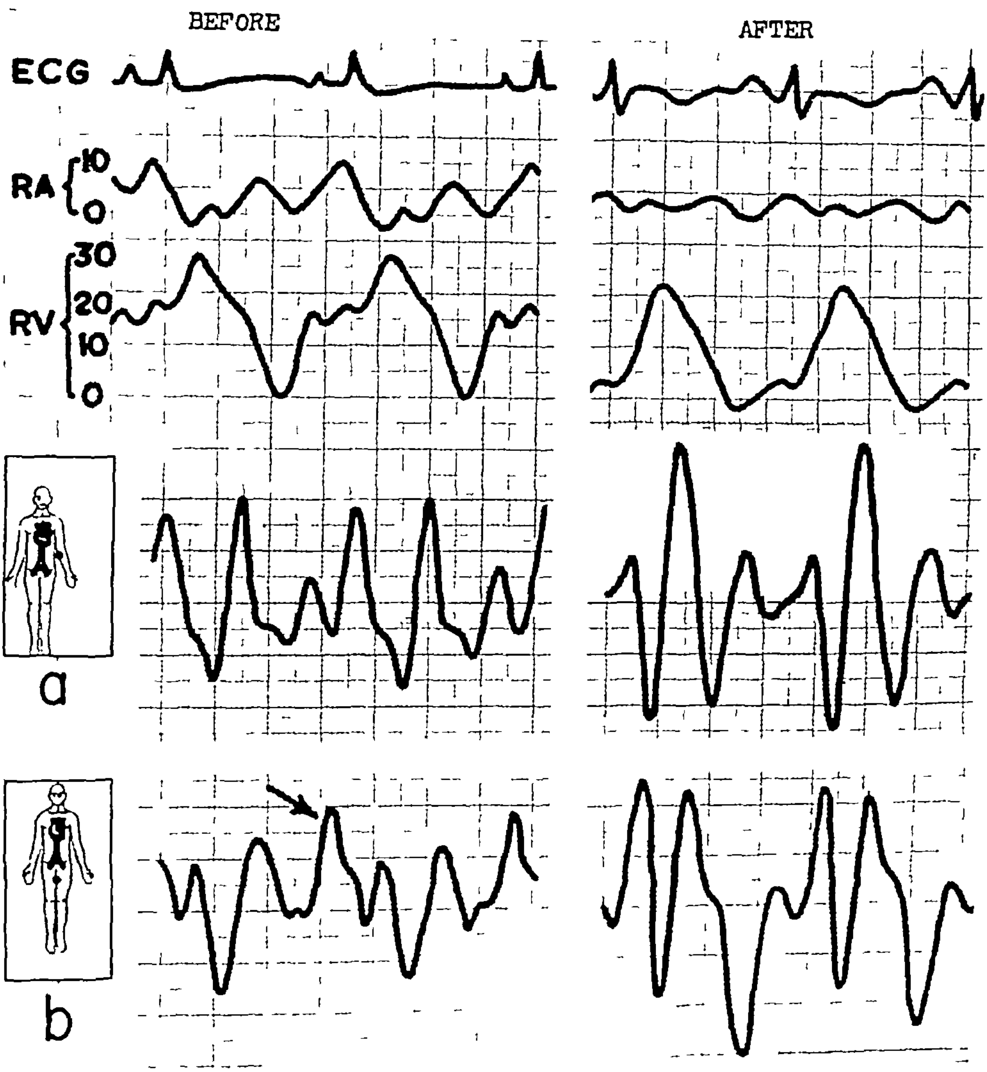

Fig 11 —Chronic constrictive pericarditis. Changes similar to those mentioned in Fig 10 correlated with right auricular and right ventricular pressure changes

This agrees perfectly with the recoil expected from blood moving through the ductus arteriosus In all cases this wave complex disappeared following operation (Fig 9)

E Chronic Constrictive Pericarditis—This condition almost invariably produces an abnormal ballistocardiogram[23, 24] the record being characterized by unusually large diastolic waves occupying most of diastole and occasionally extending into early systole Often these waves are larger than the systolic complexes It has been noted previously that these were particularly prominent in the lateral vector projection rather than the conventional head-foot position and our observations confirm this The abnormal ballistic forms are attributed to the more rapid surge of blood into the ventricle during diastole this being secondary to the elevated venous pressure and the abrupt increase in the interventricular pressure because of the inelasticity and rigidity of the ventricular walls The accentuation of these abnormal complexes by placing the patient in a position to emphasize the transverse vectors is shown in Figs 10 *b*, and 11, *b*

Following pericardiectomy there is a gradual reversion of the abnormal ballistocardiogram to a normal one although this may not occur for several months

SUMMARY

1 Torsion ballistocardiography is briefly described and its utilization in analysis of vectors comprising the ballistocardiogram is discussed

2 Abnormal ballistic complexes occurring in patients with mitral stenosis coarctation of the aorta ductus arteriosus and chronic constrictive pericarditis and their changes following operation are illustrated

3 The origin and factors causing the abnormal ballistocardiograms in these groups of cardiovascular diseases are speculatively reviewed

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THE ROLE OF THE BRONCHIAL ARTERY CIRCULATION IN THE ETIOLOGY OF PULMONARY AND PERICARDIAL SUPPURATION

AN EXPERIMENTAL STUDY

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DESPITE the gratifying decrease in the mortality of pulmonary abscess and suppurative lesions of the pericardium during the past decade their etiology remains obscure[1-3]

Most students of pulmonary abscess still maintain that the predominant etiological factor is the aspiration of infected material and disclaim the possibility of septic vascular embolism Many excellent clinical studies support this view[4-6] but the experimental evidence is not so conclusive[7-11] The many unsuccessful attempts to produce pulmonary abscesses by aspiration are in marked contrast to their almost invariable production following the introduction of a septic embolus into the jugular vein as reported first in 1926[12-16] These studies further suggested that pulmonary infarction of considerable size may be a necessary precursor to the development of an abscess Recent studies of Liebow, Ellis Shedd and their co workers supplementing the original observations of Mathes and others,[17-24] have shown that the hemorrhagic pulmonary infarction which follows massive embolism may actually be due to the destructive high-pressure inflow from the patent bronchial artery system In animals in which the bronchial artery was successfully occluded the production of massive embolism did not result in typical hemorrhagic infarction.

With these concepts in mind a series of experiments were designed to embolize the bronchial artery with multiple septic particles, to determine if possible the role of this vascular system in infections of the lung and whether massive infarction is a necessary precursor to pulmonary abscess

A few pilot experiments were performed by injecting in vivo the right posterior bronchial artery in the dog after the method of Ellis, with a suspension of India ink (Fig 1) The rapid appearance of the ink particles in the vessels supplying the pericardium and myocardium was most striking This phenomenon was evident even in the preparations in which preliminary complete ligation of both right and left coronary arteries and the pericardiophrenic

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***Assistant Clinical Professor of Pathology Stanford University School of Medicine and Chief Department of Pathological Anatomy Veterans Administration Hospital arteries at their origin had been performed (Fig 2) Many fine terminal branches of the bronchial artery could be seen accompanying the great vessels as they emerged through the pericardium These hairlike vessels continued downward over the atrial walls, particularly on the right side and anastomosed freely with the right coronary artery Numerous vessels could be seen spreading over the pericardium and anastomosing with branches of the pericardiophrenic artery, indicating the presence of direct anastomotic communications between these vascular systems These observations suggested the possibility of a hematogenic dissemination of infection to both the lung and the heart by the same vascular system

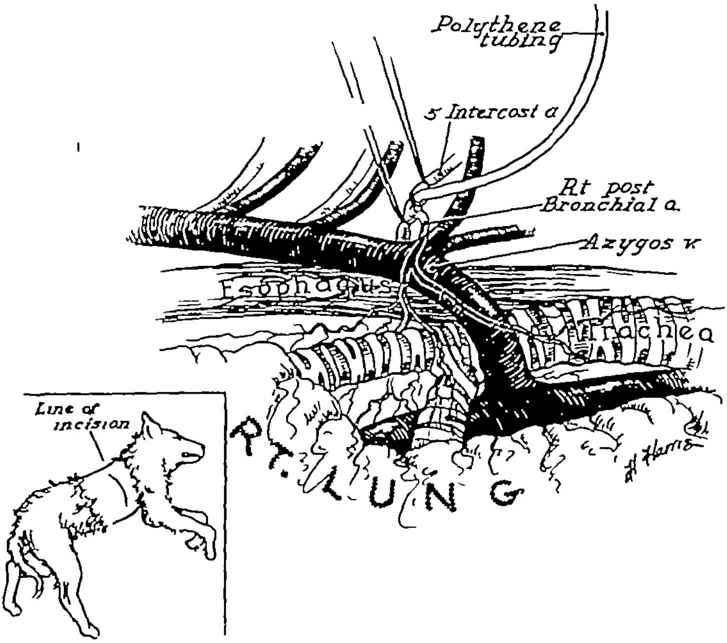

Fig 1 —The right posterior bronchial artery in the dog as exposed through a right fifth intercostal incision The parent intercostal artery has been ligated and cannulated preparatory to injection with septic emboli

A review of the literature yielded little information concerning the extrapulmonary ramifications of the bronchial circulation A casual mention of the bronchial artery supply to the mediastinal organs was made by Cauldwell and Anson with their co-workers,[7, 9] Berry and Daly [24] and Horne and Warner [6] In 1932 Hudson, Moritz and Wearn[2] demonstrated filling of the bronchial artery by injections into the coronary circulations of the human heart More recently Tobin[28] has made brief reference to the bronchial arteries which supply the mid-portion of the esophagus, tracheobronchial lymph nodes, the vasa vasorum of the pulmonary artery and the visceral pleurae

METHOD

Adult mongrel dogs weighing 8 to 20 kilograms were used Animals in which the presence of recent pulmonary disease was suspected were discarded Veterinary Nembutal, 30 mg per kilogram of body weight, and mechanical respiration were routinely employed A standard right posterolateral thoracotomy was performed through the fifth intercostal space (Fig 1) The right posterior bronchial artery was identified as it arose from the fifth, or sometimes from the fourth or sixth intercostal artery The parent intercostal artery was ligated proximally and distally to the origin of the bronchial vessel, care was taken to avoid extensive dissection which would disrupt minute vessels The azygos vein was not divided The segment of intercostal artery between the ligatures was cannulated with polythene tubing, the inside diameter of which just snugly admitted a No 20 gauge needle A standardized quantity of septic material was injected, the cannula removed, and the vessel ligated permanently Extreme care was taken to avoid gross contamination of the surrounding tissues, routine closure of the chest wall was performed No drains or antibiotics were employed

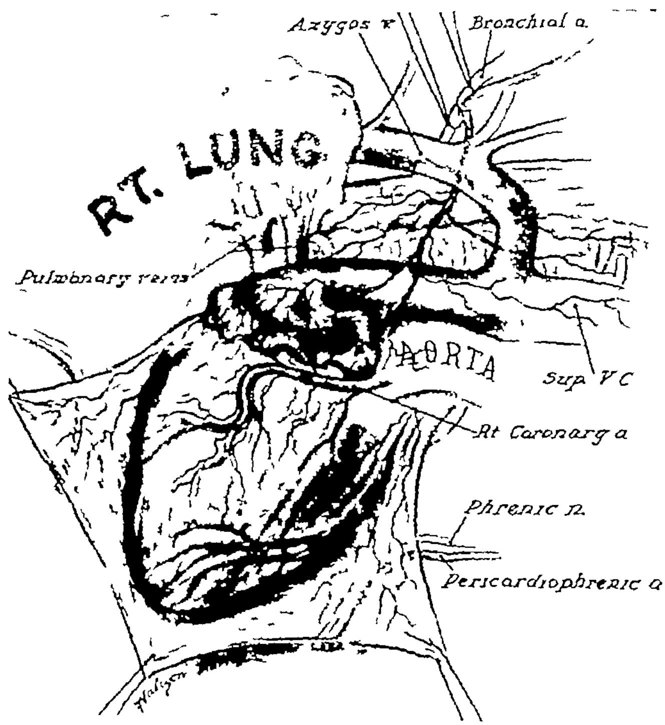

Fig 2—Diagrammatic reproduction of the extrapulmonary ramifications of the right posterior bronchial artery after India ink injection Direct anastomotic communications with the right coronary and pericardiophrenic arteries are demonstrated

Two series of animals were studied Group I dogs received a standard 18 to 24-hour old blood subculture inoculum of *Staphylococcus aureus* The dosage was arbitrarily calculated on the basis of 0 5 c c per five kilogram of body weight Fragments of fibrin and clot were employed as the embolic particles The organism had been isolated from an infected posttonsillectomy fossa

Group II dogs received the same organisms cultured in a glucose broth media To this was added 1 c c of a freshly prepared suspension of barium sulfate, U S P In a few dogs Hill s* mass was employed The dosage of this mixture was similarly calculated from body weight Barium was used because it would provide a greater number of particles and also because its dissemination in the superficial vessels could be immediately visualized

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*Hill s mass is prepared from 200 Gm. of bismuth oxychloride 100 Gm of gum acacia, and 100 c.c. of distilled water

RESULTS

Thirty animals were studied These were equally divided into two groups

Group I—Of fifteen dogs in this series, all but two animals survived indefinitely without visible evidence of suppurative pulmonary disease There was microscopic evidence of healed inflammatory processes in the visceral parietal, and mediastinal pleurae Minimal healed inflammatory lesions of the pericardium, esophagus, and tracheobronchial tree were observed The parenchyma of the lung was essentially normal No definite pulmonary abscess was found

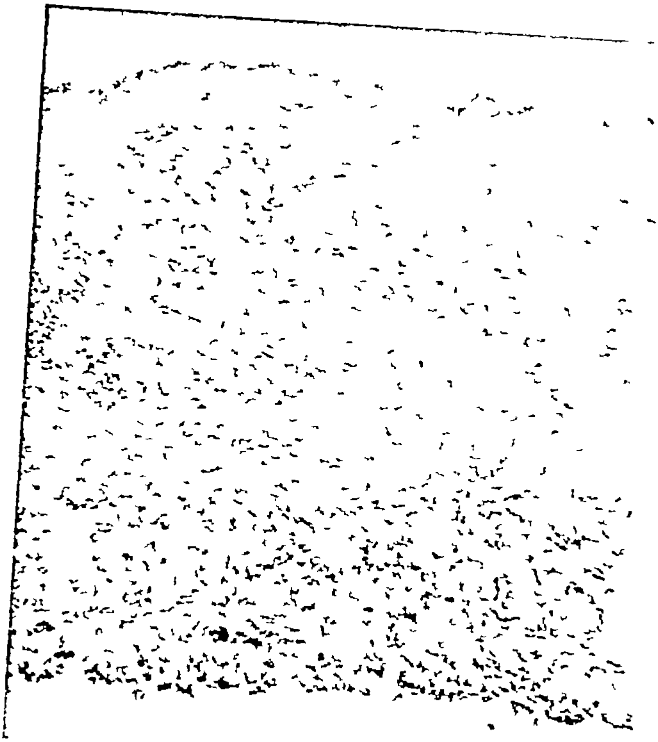

Fig 3—Photomicrograph of pericardium from animal in Group I demonstrating considerable thickening and evidence of acute inflammation throughout (hematoxylin and eosin ×80)

Two animals died at five and six days respectively, of acute cardiac tamponade secondary to a purulent pericarditis with effusion Grossly, there was empyema and diffuse cellulitis of the chest wall All pleurae were intensely injected and the mediastinal space was filled with sanguinopurulent fluid The esophagus, trachea and major extrapulmonary bronchi bilaterally revealed evidence of acute transmural suppuration The pericardium was tautly distended with sanguinopurulent fluid It was grossly hemorrhagic and infected

Microscopically there was considerable thickening with acute and subacute inflammatory lesions throughout (Fig 3) The myocardium was normal The epicardium revealed a peripheral zone of acute inflammatory reaction The lungs were normal with the exception of a visceral pleuritis No gross or microscopic evidence of pulmonary infarction suppuration or abscess was found

Group II—Fifteen animals were in this series The longest survival was one week All of the remaining animals died within twenty four to forty-eight hours In thirteen animals the immediate cause of death was acute necrotizing myocarditis Grossly there was empyema and cellulitis of the chest wall of a more severe degree than was observed in the two animals of Group I. The chest cavity was often filled with sanguinopurulent fluid as was the mediastinal space An intense hemorrhagic inflammatory reaction of all pleurae, the esophagus trachea and bronchi, and even the adventitia of the aorta was observed

The pericardium was similarly involved and varying degrees of pericardial effusion were consistently encountered In thirteen specimens gross hemorrhagic zones were found chiefly in the right ventricle and atrium. Particles of barium were seen grossly in the right coronary artery (Fig 4) The lesions varied from small, subendocardial to extensive transmural areas of involvement In a few hearts, lesions of the left ventricle were seen posteriorly where intercoronary artery communications with the circumflex branch of the left coronary artery were present No lesions of the area supplied by the left anterior descending artery were observed

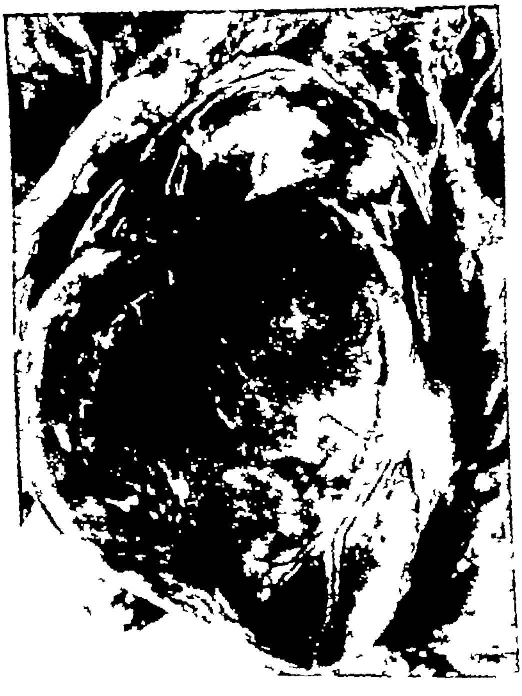

Fig 4—Typical heart from a Group II animal The areas of right ventricular hemorrhage with barium particles in the right coronary arteries are demonstrated A hemorrhagic lesion of the fatty tissue overlying the right atrium can be seen

Microscopically the lesions appeared to be typical of acute necrotizing myocarditis with interspersed areas of hemorrhage acute inflammation and destruction of the myofibrils (Fig 5) Barium and staphylococcal emboli were frequently seen in the vessels of arteriolar size The most intense inflammatory response was centered about the staphylococci In several arterioles where there was relatively complete separation of the barium particles from the staphylococci little or no inflammatory reaction appeared around the barium emboli These findings substantiate the results obtained in two animals where barium was injected without organisms The animals survived without evidence of hemorrhagic inflammatory vascular lesions It would appear that the organisms and not the barium were responsible for the characteristic hemorrhagic pathology

In contrast to the Group I animals all but two dogs in Group II showed marked pulmonary parenchymal lesions (Fig 6) Grossly these appeared as bilateral areas of consolidation usually lobar in distribution On incising the lung whole blood poured forth

Microscopically, the lesions appeared neither like that of acute consolidative pneumonitis nor hemorrhagic infarction (Fig 7) The alveoli were filled with erythrocytes and a highly proteinic exudate containing little or no inflammatory elements Closer inspection of the intramural branches of the bronchial arteries showed focal lesions of intense inflammation, often with rupture of the vessel wall which apparently accounted for the blood seen in the alveoli Numerous emboli consisting of barium particles and staphylococcus organisms were seen within the lumen of the vessels Again, no discrete pulmonary abscess, as such, was observed

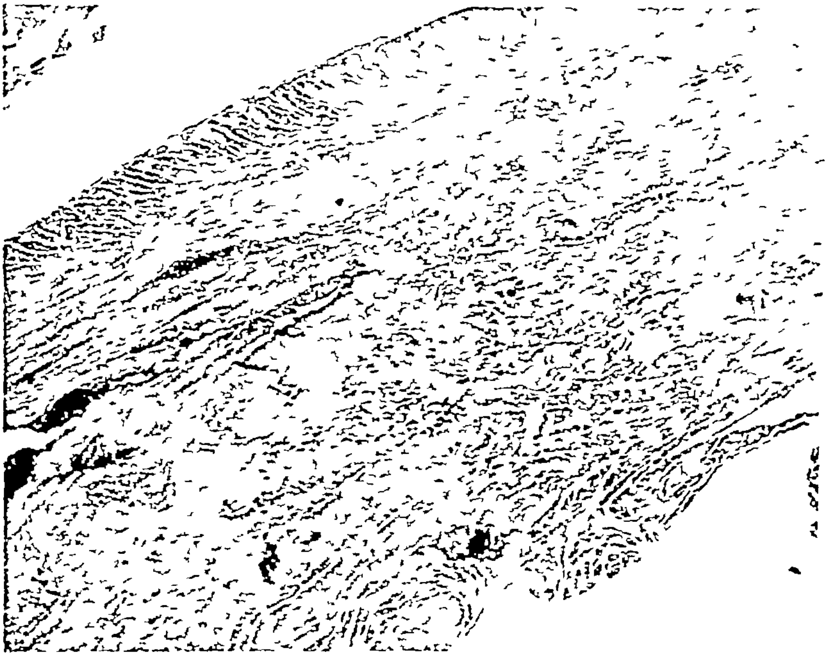

Fig 5—Photomicrograph of hemorrhagic myocardial lesion depicted grossly in Fig 4 The epicardium is above the endocardium below Zones of hemorrhage are seen in the lower left with deeply staining clumps of staphylococci distributed among the myofibrils Acute inflammatory elements surround most of the staphylococcal emboli (hematoxylin and eosin ×17)

DISCUSSION

Experiments have been described in which an attempt was made to evaluate the role of the bronchial artery as a route for hematogenic infection of the lungs and pericardium Under the conditions of the experiment, the use of small particles of infected blood clot in the animals Group I resulted uniformly in failure to produce pulmonary suppuration These consistently negative results may be ascribed to the variable factors of host resistance, a too low virulence or inadequate dose of the organisms, or to an inadequate number of embolic particles employed

It would appear that the higher incidence of pulmonary lesions observed in the animals in Group II can be attributed to the greater number of embolic particles which were successfully trapped, and not to the factors of resistance dosage, and virulence of the organisms Despite the more successful embolization of the bronchial artery circulation in Group II, no suppurative pulmonary

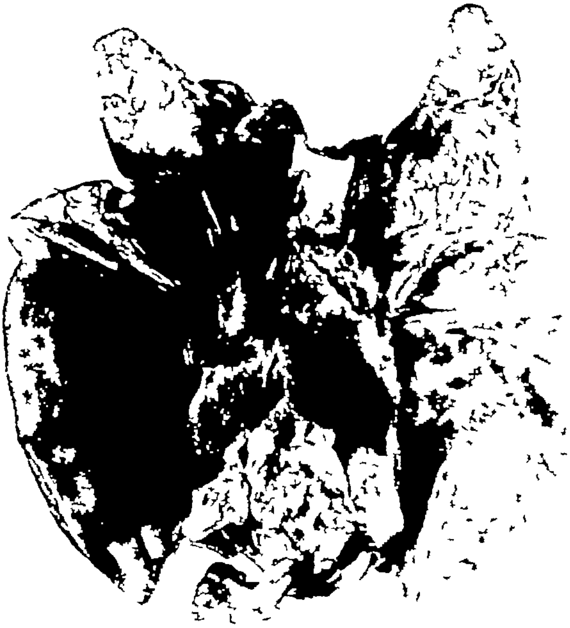

Fig 6—Gross specimen from typical Group II animal There are marked hemorrhagic lesions involving the mediastinal pleura, trachea and pericardium. The right lung is dark, heavy and nonair-containing as compared to the normal left lung

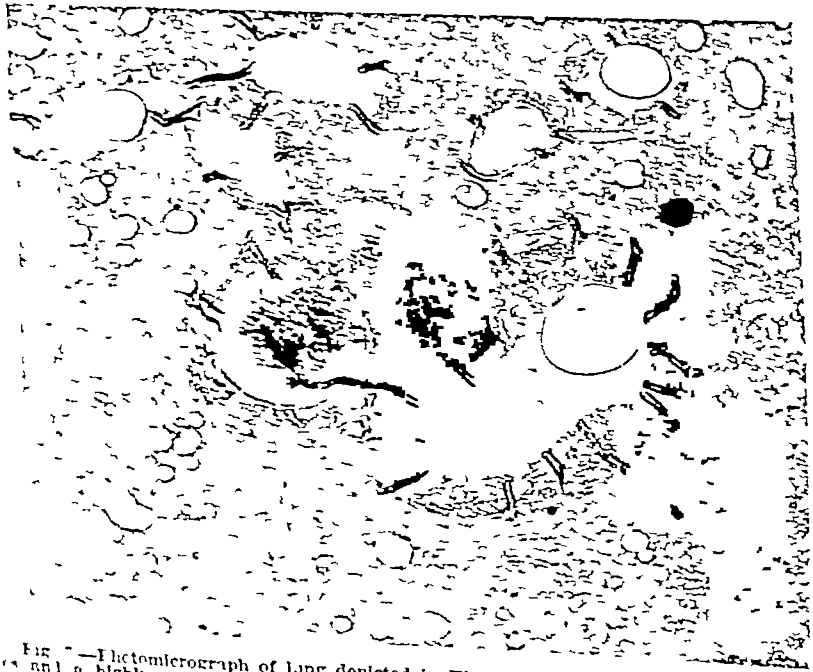

Fig 7—Photomicrograph of lung depicted in Fig 6 The alveoli are filled with erythrocytes and a highly proteinic exudate An intrapulmonary bronchus is seen to the left of center a pulmonary artery on the right A circumscribed lesion is seen within the wall of the bronchus consisting of staphylococci barium particles and polymorphonuclear leukocytes There is an irregularity of one quadrant of the lesion suggesting rupture of its containing bronchial artery wall (hematoxylin and eosin ×33)

lesions were observed. Likewise, no true pulmonary infarction was demonstrated in either series of animals. There is little doubt that the greater part of the bronchial artery blood flow was successfully occluded in Group II. The pulmonary arteries or veins did not contain barium emboli on microscopic examination.

The unexpectedly high incidence of myocardial and pericardial lesions was of great interest. The difference between the two animals in Group I which demonstrated primarily a pericardial involvement and the nine animals in Group II which uniformly presented additional myocardial lesions is again, we think, a matter of relative numbers of embolic particles employed. It is possible that embolic particles could have reached the myocardial capillary bed simply by direct shunting from bronchial arteries to pulmonary veins and then out the left heart. However, sections of tissues supplied by the systemic circulation have failed to reveal the presence of barium emboli. Moreover, it would seem to be unusual for the emboli to distribute so uniformly to the right ventricle and to avoid the left ventricle. The existence of these communicating anastomotic channels as demonstrated by the injection of India ink was demonstrable even when the entire coronary and pericardial arterial blood supply was completely ligated at its source. It is conceded, however, that more accurate methods of determining the exact route of dissemination should be studied further.

In summary, it would appear that the bronchial artery in the dog has a degree of ramification and collateralization hitherto not appreciated. Multiple septic emboli disseminated by this system did not produce definite pulmonary infarction or abscess. Indirectly, these results support the theory that pulmonary infarction is a necessary precursor to the pulmonary abscess produced by a vascular septic embolus. In view of the rapid death of Group II animals further studies are indicated. The high incidence of lesions of the mediastinal organs, pleurae, chest wall, heart, and pericardium suggest that the bronchial artery is more important as a mediator of infection to these structures than to the bronchopulmonary organs with which we usually associate this vascular system. The clinical importance of these observations deserves further study.

CONCLUSIONS

1. Multiple septic emboli injected into the right posterior bronchial artery of the dog failed to produce pulmonary infarction, suppuration, or abscess.
2. In contrast, there was a high incidence of suppurative lesions of the mediastinal organs, pleurae, chest wall, heart, and pericardium.
3. The anatomic communications between the bronchial and pericardial and intrinsic coronary artery systems have been demonstrated by India ink injection.

We are indebted to Miss Alice Violante and Mr. Dusan Surman for their kind assistance in this work.

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BRONCHOPULMONARY SARCOMA

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PRIMARY sarcoma of the lung is notably rare. If the diagnosis is limited to tumors composed of spindle-shaped cells of probable mesodermal origin, the majority of recorded cases can be eliminated. It is the purpose of this paper to consider the clinical and morphologic features characteristic of bronchopulmonary sarcoma and to discuss the differentiating criteria of its more frequent imitators.

REVIEW OF LITERATURE

In 1931, Ball[1] was able to collect only fifteen examples of pulmonary sarcoma from the European and American literature of the preceding thirty years. The majority of these were classified as "round-cell sarcomas," and only seven represented tumors composed of spindle-shaped cells.

The validity of cases reported since 1931 is equally difficult to determine. There is doubt as to the exact origin and histogenesis of some of the tumors. For example, four of the sarcomas occurred in women on whom hysterectomy had previously been performed.[2-5] Of these, only Cote's case, because of the location and morphologic features of the tumor, deserves serious consideration as a primary bronchopulmonary sarcoma. Likewise, pleura or mediastinum cannot be positively excluded as the site of origin of the tumor reported in other patients.[6-10] Many authors continue to report pulmonary sarcomas composed of round or poorly differentiated cells. These according to inferences from the descriptions, may be variously interpreted as undifferentiated cell carcinomas or one of the types of lymphoma.[7, 11-19] Other omissions from the series are three cases in which the microscopic descriptions are incomplete[10, 21] and three cases referred to in general articles.[22-24]

Thus, the medical literature from 1931 to 1950 contains only nine examples of spindle-cell sarcoma of probable pulmonary origin, raising the total of reported cases to sixteen for the period 1900 to 1950.

CASE REPORTS

In the material indexed at the Armed Forces Institute of Pathology as sarcoma of the lung are three additional examples which are similar, clinically and morphologically, to those selected from the medical literature. All three were intrapulmonary tumors composed of spindle cells associated with collagen or reticulum. Two of them came to clinical attention early in the course of the disease, when the patients were given routine x-ray examination. In all three cases the tumors were removed surgically, and in two the postoperative course has been uneventful in respect to recurrence or metastasis.

From the Armed Forces Institute of Pathology.

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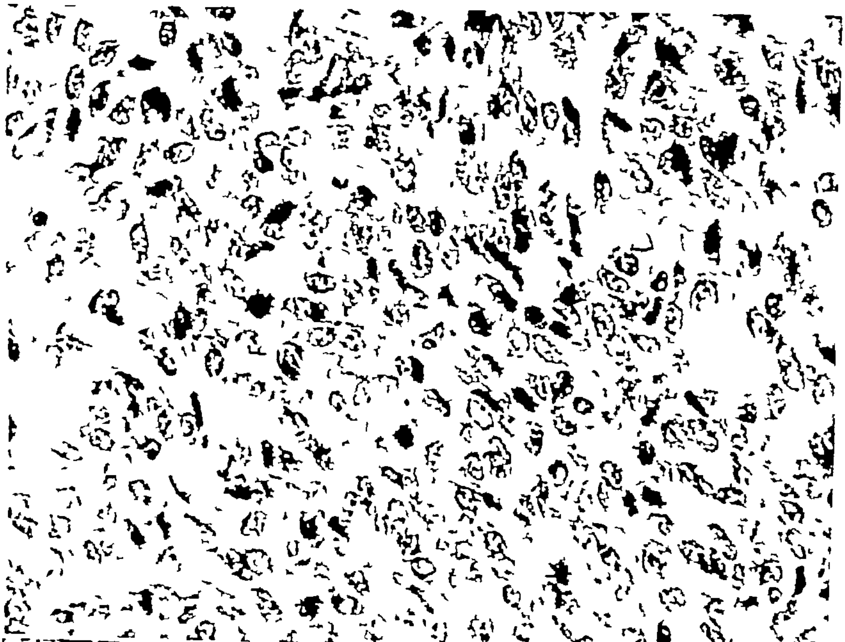
Fig 1



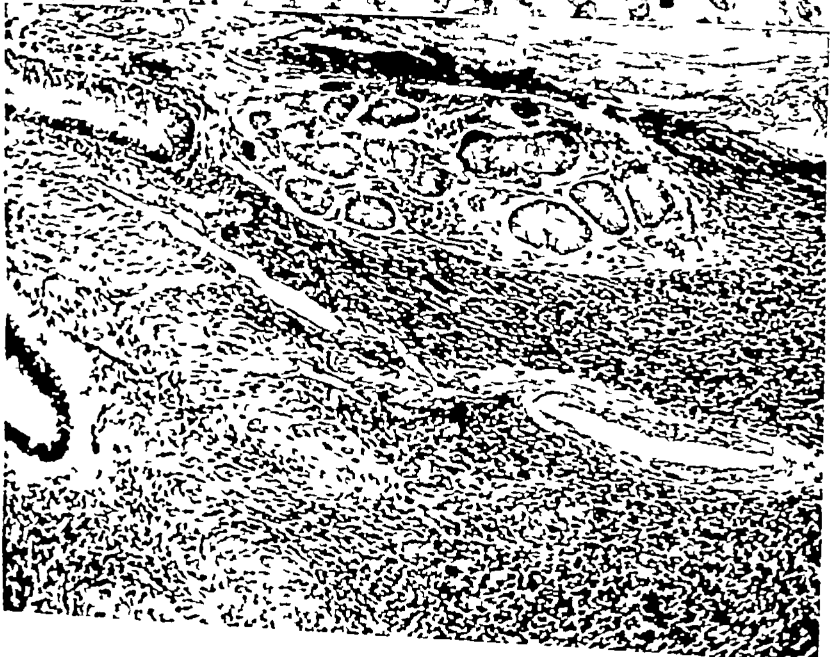


Fig 2

Fig 1—Intrapulmonary spindle cell sarcoma well localized tumor composed of oval and spindle shaped cells Delicate fibrils associated with the tapering cytoplasmic poles Hematoxylin and eosin ×400 AFIP Acc. 161584

Fig 2—Intrapulmonary spindle-cell sarcoma this field resembles undifferentiated cell carcinoma of bronchus Note tendency to sparing of glands and muscle bundles. Silver stains demonstrated reticulum Hematoxylin and eosin. ×100 AFIP Acc. 161584

Case 1—AFIP Acc 161584 This 28 year old white man had been without symptoms of any kind until his separation from the Army Routine chest x ray examination at that time revealed a rounded shadow in the upper lobe of the left lung Bronchoscopic examination showed no abnormalities

A firm, round mass was removed from the upper lobe of the left lung On section, this proved to be a cyst measuring 4 5 by 3 5 cm, located near the hilum and containing yellow, gelatinous material A secondary bronchus opened into the cyst and the bronchial mucosa was continuous with its smooth lining The cyst wall was 2 mm thick except at its lateral border where it merged with a nodular mass measuring 1 cm in diameter Microscopic sections showed the tumor to be composed of plump but elongated cells associated with reticulin formation (Fig 1) There was local invasion of the wall of a small bronchus by the oval spindle shaped cells (Fig 2)

The patient's progress was followed until four years after lobectomy He remained free from evidence of recurrence or metastasis of the tumor Three years postoperatively there was enlargement of the glands of the right axilla, but biopsy revealed only chronic lymphadenitis

Case 2—AFIP Acc 210940 The patient was a 60 year old white man Although he had had no symptoms, an x ray film of the chest taken during a general survey revealed a mass in the upper part of the right lung Three months later, further x ray examination confirmed these findings and a presumptive diagnosis of pulmonary cyst was made

Right upper lobectomy was performed The lung contained a solid globular mass 9 by 8 5 cm The tumor was well circumscribed and the pleura overlying it was smooth (Fig 3) At one point the friable, grayish white neoplastic tissue infiltrated the wall of a bronchus which was involved in the mass Histologic preparations showed well-differentiated spindle shaped cells with elongated reticulin positive cellular fibrils (Fig 4)

No metastasis was demonstrable at the time of operation, and three years later there was no evidence of recurrences

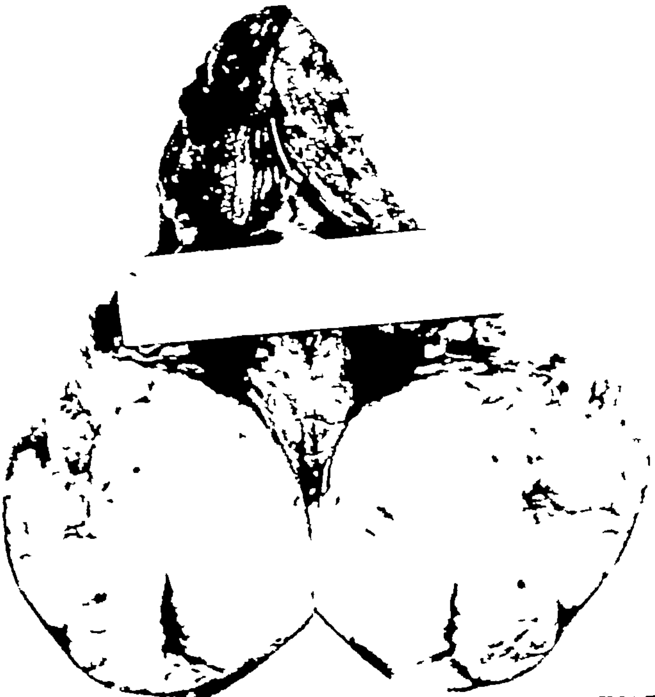
Case 3—AFIP Acc. 271509 The patient was a 47 year old white man One year previously, at his annual physical examination, electrocardiograms and chest films had shown no abnormalities Nine weeks prior to admission he complained of "tightness in the left chest" which interfered with deep respirations At this time, x ray examination of the chest revealed a lesion in the lower lobe of the left lung, and a diagnosis of pneumonia was made The diminished breath sounds, decreased expansion, and inspiratory râles did not improve with therapy Subsequent x ray films demonstrated a mass, measuring 8 cm, in the suspected area, associated with elevation of the left leaf of the diaphragm. The mass rapidly increased in size during the first five weeks of hospitalization The lung fields otherwise remained clear except for pleural thickening over the tumor

Exploratory thoracotomy was performed two and one half months after the onset of symptoms and a lobulated, grayish, friable tumor occupying the lower lobe of the left lung was removed On gross examination no abnormalities of the bronchial tree and vascular system and no metastases were observed Neither was there evidence of any possible primary site, other than the pulmonary parenchyma X ray therapy was administered postoperatively, it was again administered six months later, when the mass recurred The patient's pain and dyspnea progressed until death, approximately one year after lobectomy Post mortem examination revealed tumor occupying the remainder of the left lung and a metastatic nodule in the lower lobe of the right The original surgical specimen, like the metastatic nodules at autopsy, was composed of poorly differentiated spindle shaped cells The cells were associated with reticulin formation except in areas of necrosis, and more solid portions were marked by collagenous intercellular material (Figs 5 and 6) There was local invasion at the periphery of the primary tumor (Fig 7)

CHARACTERISTICS OF BRONCHOPULMONARY SARCOMA

These three cases, together with the sixteen examples selected from the medical literature from 1900 to 1950, are included in the total of 19 cases of

Fig 3



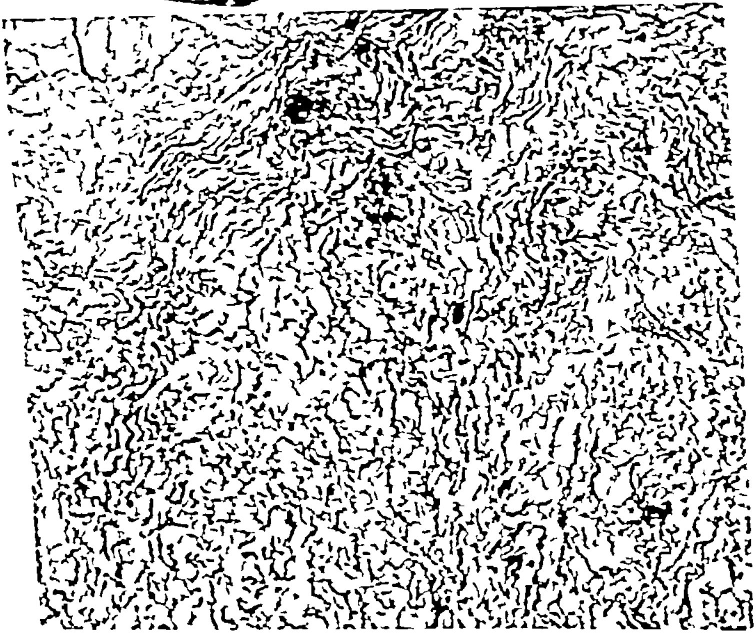


Fig 4

Fig 3.—Intrapulmonary spindle-cell sarcoma (surgical specimen), a characteristic localized solitary primary tumor encroaching on bronchus. AFIP Acc. 210940.

Fig 4.—Intrapulmonary sarcoma; reticulum formation helps to differentiate the tumor as a sarcoma. Reticulum stain ×275. AFIP Acc. 210940.

Fig 5

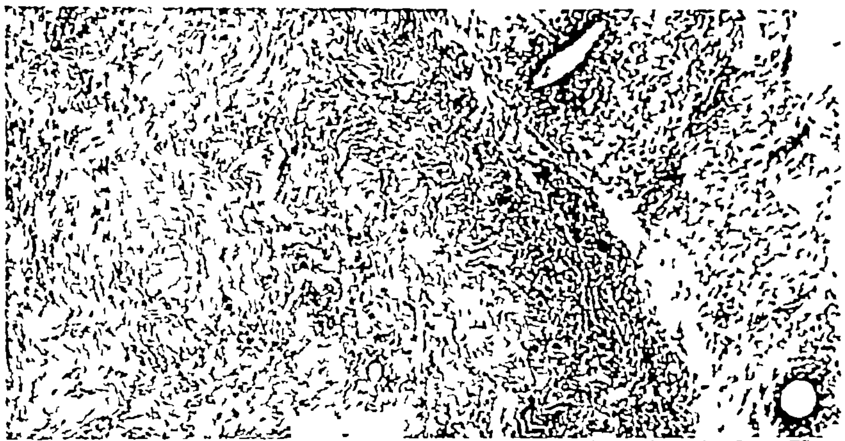


Fig 6

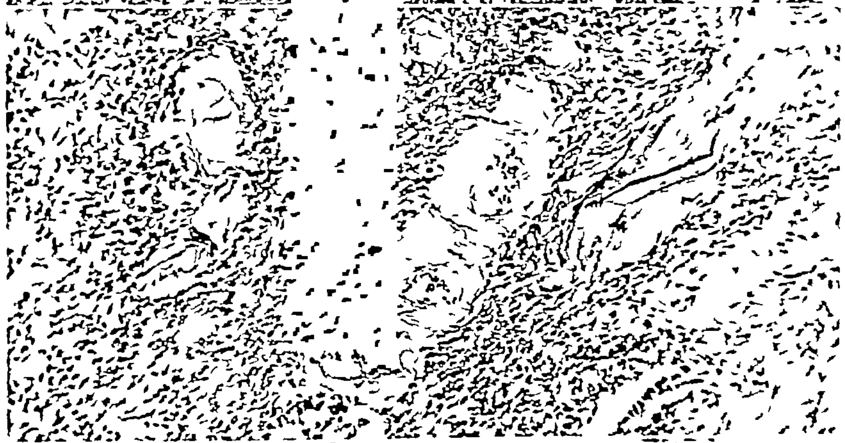


Fig 7

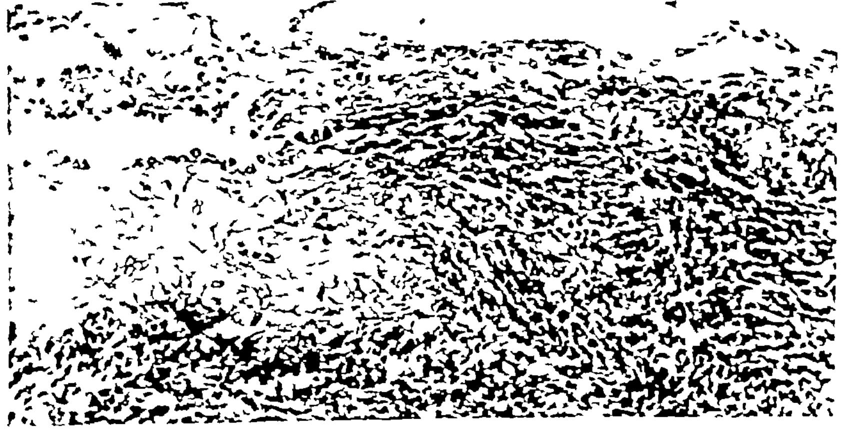


Fig 5—Intrapulmonary spindle cell sarcoma an area of collagenous fibers produced by the well differentiated spindle-shaped cells borders a zone of necrosis where the tumor resembles reserve cell carcinoma Masson stain ×60 AFIP Acc. 271509

Fig 6—Intrapulmonary spindle-cell sarcoma in some areas the thick walled vessels and collagen production suggest a benign tumor Hematoxylin and eosin ×100 AFIP Acc 271509

Fig 7—Intrapulmonary spindle-cell sarcoma incomplete encapsulation of tumor resulting from expansile type of invasion by the poorly differentiated spindle-shaped cells Hematoxylin and eosin ×185 AFIP Acc. 271509

intrapulmonary spindle-cell sarcoma summarized in Table I It should be noted that this series, in order to include only those tumors of relatively certain pulmonary origin, necessarily represents a prejudiced sample of either early or premetastatic examples (Table I)

Morphologic Characteristics of Intrapulmonary Sarcoma—Primary sarcoma of the lung is characteristically a solitary firm white tumor (Fig 3) occurring in middle-aged persons Sections from the tumors in the three cases reported here were compared with known sarcomas arising elsewhere and metastasizing to the lung Attention was given to encapsulation, morphologic characteristics of the tumor cells and extent of the tumor Descriptions contained in the literature were also utilized in this study

In the primary tumors the capsule where intact was dense and fibrous, but it was not always adequate to restrain the tumor which advanced through it and into the adjacent parenchyma in a broad, expansile fashion (Fig 7) The degree of encapsulation tended to vary with the degree of cellular differentiation Although some metastatic sarcomas were nodular poorly encapsulated and multiple others demonstrated gross features identical with those of primary sarcoma

In most of the microscopic sections the neoplastic cell was spindle-shaped or oval often with the nucleus blunted at one pole and tapering at the other (Figs 1, 2 and 7) Rare portions of these tumors bordering areas of hemorrhage and necrosis contained cells which in cross section appeared indistinguishable from lymphoid or "oat cells" except for the poorer chromatin content of their nuclei (Fig 5) In these more cellular zones the tumor cells collected around thin walled vessels In all areas reticulin honeycombed the tumor, forming recesses for one or several cells, and was occasionally reinforced by varying amounts of other intercellular substance (Figs 4 and 6) In the more compact portions of the tumor the cells tended to be more elongated and the reticulum more dense Sometimes fine undulating fibrils closely packed together formed the background for extremely well-differentiated serpentine cells (Fig 6)

Case 2 in this series is representative of a small number of other descriptions in the literature in which the neoplastic cell as in leiomyosarcoma is uniformly large and well differentiated possessing abundant cytoplasm In these there were few mitoses The cells were bundled together compactly and were intimately associated with tapering eosinophilic fibers staining for reticulum

In summary pulmonary sarcomas are composed of spindle-shaped cells productive of varying amounts of intercellular material or cellular fibrils which may stain as collagen reticulum or smooth muscle More often reticulin is the only positive staining product

Behavior of Intrapulmonary Spindle Cell Sarcoma—The peripheral location of spindle cell sarcomas of the lung gives rise to such nonspecific symptoms as dyspnea fever or malaise Thus the clinical course is likely to be of long duration unless the lesion is an incidental discovery during routine examination Because of its circumscription the tumor lends itself readily to removal by

TABLE I INTRAPULMONARY "SPINDLE CELL" SARCOMA, CASES REPORTED 1900 1952

AUTHOR YEAR	AGE	SEX	DURATION	CLINICAL	GROSS RELATIONSHIP	EXTENSION OR METASTASES	MICROSCOPIC
Kobylinski[25] (Quoted by Ball) 1904	16	M	Asymptomatic		Left upper lobe Small firm tumor	None	Fibrosarcoma
Boschowsky[26] 1912	56	M	Not stated	Chest pain, cough, dyspnea	Left lung Large tumor, well circumscribed, encapsulated	None	Spindle cells, varying degrees of differentiation
Stevens[27] 1912	24	M	4½ mo	Dyspnea, pain, cough, swelling of rt. chest	Right lung Almost replaced by firm gray tumor	None	Spindle cell sarcoma
Pritchard[28] 1921	23	F	16 mo	Acute onset of fever, hemoptysis cough, 3½ cm mass by x ray, 10 mo later 7 × 7¼ cm At operation, 12 × 10 cm	Right mid lung Circumscribed, semisolid tumor, 800 Gm	None	Spindle cell sarcoma
Campatelli[29] 1926	53	F	30 mo	Dyspnea, cough, vomiting	Right upper lobe Right mid lung Firm, white tumor	None	Typical spindle cell "fibrosarcoma"
Edwards[30] (Case 5) 1927	60	M	3 yr	Hemoptysis, cough, recent back pain	Right lower lobe Firm, white lobulated tumor	None	"Plexiform sarcoma"
Ball[1] 1931	51	M	32 mo	Cough, stuporous episodes, night sweats 7 mo before death	Left lower lobe Firm, gray tumor, 20 × 20 × 13 cm	None	Spindle cells with intercellular material, major portion poorly differentiated
Scheidegger[31] 1931 1932	49	F	7 mo	Pleural effusion, dyspnea, edema, cystic mass, entire left lung	Left lower lobe Large, well circumscribed tumor	None	Portions of tumor, dense, solid "like fibroma", others "like sarcoma", some giant cells
Mysh[32] 1933	38	M	2 yr	Cough, dyspnea	Left upper lung Well circumscribed tumor	(Surgical specimen) none	Spindle cell sarcoma
Lyssunkin[33] 1935	48	F	2 yr	History of tbc cough, chest pain, signs cardiac failure for 2 yr, mass rt lung Cachexia	Right lower lobe Well circumscribed intrapulmonary tumor 20 × 16 × 11 cm central portion firm and white, outer zone soft and necrotic, tuberculosis and bronchiectasis	None	Collagen producing spindle cells, atypical mitoses, fat containing cells in edematous peripheral portion
Johns and Sharpe[34] 1935	18	M	15 mo	Cough, hemoptysis, sputum, loss of wt., 6 cm density right lung enlarging and extending to pleura	Right lung Tumor occupying most of right lung, extending along wall of right main bronchus and protruding into lumen	Heart, via pulmonary vessels, opposite lung	Mitoses common, very cellular, spindle and round cells, silver stains show reticulum

Mass General Hospital Case 22411[35] 1936	17	F	1 mo	Pain, cough, dyspnea	Right lower and middle lobes Circumscribed, solid, lobulated mass	Small solitary nodules on liver surface, kidney, spleen, opposite lung Pleura overlying tumor	Well differentiated fibrosarcoma in primary tumor and spleen, multinucleated giant cells in secondary liver and lung nodules Spindle cells, positive reticulum
Stohr and Sachs[36] 1937 1938	51	M	15 yr ? 6 7 yr ?	Joint pains, dyspnea, hypophyseal cyst	Right lower lobe Tumor "size of man's head", well circumscribed		
Mass General Hospital Case 21172[37]	63	M	1 mo	Pain operation 1 mo after onset	Left lower lung Sharply defined, lobulated tumor within lung	(Surgical specimen) none	Fibrosarcoma of spindle cells
Ellis[38] 1939	51	M	2 yr	Fever, cough, night sweats for 2 yr, paralysis and convulsions for 1 mo	Right middle lobe Soft friable well circumscribed tumor 8 × 5 × 5 cm located toward periphery, 3 × 2 × 2 cm mass at hilum protruding into bronchus	Brain hilar node	Small interlacing spindle shaped cells in dense sheets, very vascular, areas of necrosis, reticulum positive
Mass General[39] Hospital Case 31271 1945	65	M	1 yr	9 mo weakness, pulmonary osteoarthropathy, died 3rd mo P O with pneumonia and widespread skeletal metastases	Right lower lobe Large, round, well encapsulated tumor, necrotic areas	Bone	Fibrosarcoma
MGH NO 161584	28	M	Asymptomatic	Round density by routine x ray examination	Left upper lobe Cystic mass 4 5 × 3 5 cm with 1 cm nodule in cyst wall	None, 1 yr P O living and well	Spindle cell sarcoma with foci of intercellular collagen, reticulum formation
210910	60	M	Asymptomatic	Density discovered by mobile x ray unit	Right upper lobe 9 × 8 5 cm, solid globular white tumor pleura intact, bronchus infiltrated in one area	None, 3 yr later, patient living and well	Well differentiated spindle cell sarcoma
271509	47	M	2½ mo	Tightness in chest, mass by x ray P O x ray therapy Mass recurred 6 mo after operation Death 11½ mo after onset	At operation left lower lobe 5 cm lobulated friable, grayish tumor At autopsy remainder of left lung involved	None at operation Right lower lobe at autopsy	Spindle cell sarcoma producing reticulum and varying amounts of intercellular material

lobectomy or pneumonectomy Analysis of Table I reveals that metastasis, recurrence, or extension occurred in only six of the nineteen examples, the absence of metastasis in the majority of remaining cases was demonstrated at autopsy after a clinical course averaging seventeen months

These data indicate that intrapulmonary sarcoma is typical of other "low grade" sarcomas in that it is slow growing, tends to be well-circumscribed, and may effect no undue hardship on the patient if it is removed early and completely It may, however, metastasize to bone or distant organs

Although the infrequent metastasis or recurrence seems to assure a relatively good prognosis, sarcomas arising in the lung may be presumed to share the surprising potentiality for late metastasis observed in tumors of similar histologic types originating elsewhere, and it is presumed that further follow-up studies of the present series will elicit examples of unusual metastasis years after the removal of the primary tumor

DISCUSSION

The clinical and anatomic data presented offer criteria by which pulmonary spindle-cell sarcoma may be defined There are, however, other infrequently occurring tumors which are of importance to clinicians and pathologists in their combined approach to the diagnosis of bronchopulmonary sarcoma These are (1) endobronchial sarcoma, (2) miscellaneous rare types of sarcoma such as chondrosarcoma, rhabdomyosarcoma, and liposarcoma, and (3) lesions that may imitate primary sarcoma of the lung

Endobronchial Sarcomas.—Occasionally a sarcoma may arise in one of the main bronchi, there producing endobronchial obstruction (Fig 8) This may be distinguished from sarcoma arising in the parenchyma not only by the symptoms resulting from its peculiar location but also by apparent intrinsic differences in the neoplasm itself

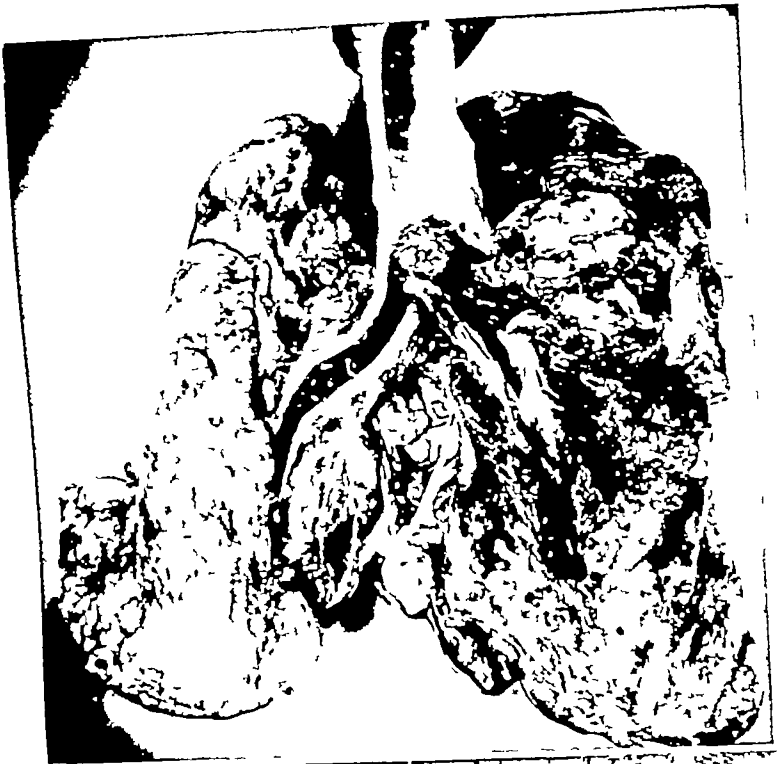
In 1950, Black[40] collected from the literature at least four cases which he designated fibrosarcoma of the bronchus, and recorded another example Three additional cases were reported by other authors to bring the total to eight[41-43] These are summarized as "endobronchial spindle-cell sarcoma" in Table II

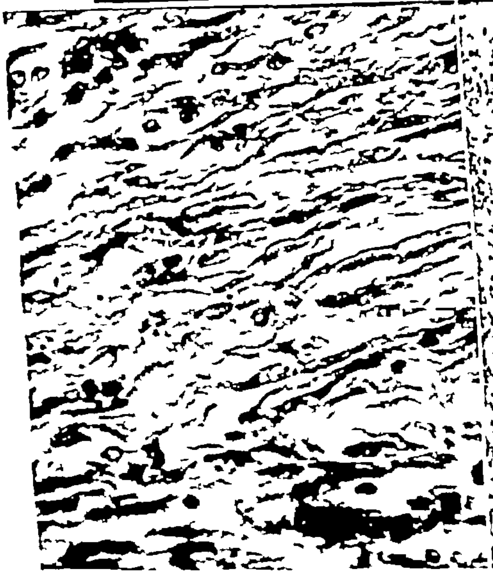
The descriptions in Table II and study of sections from Cases 5 and 7 indicate that the cell type characteristic of these polypoid endobronchial tumors is large and plump with an oval vesicular nucleus (Fig 9) The cells, usually better differentiated than those forming the majority of parenchymal sarcomas, may be blunt, tapered, or prolonged into fibrils which are silver-positive when stained for reticulum

Although the exposed surface lends itself readily to biopsy, the diagnosis is made exceedingly difficult by these well-differentiated mesodermal neoplastic cells which, in the presence of secondary inflammation, may easily be mistaken for reticulo endothelial cells or organizing fibroblasts (Figs 10 and 11) Only when the entire tumor is studied following pneumonectomy or at autopsy does the neoplastic nature of the cell seem to be convincingly demonstrated

A review of the clinical behavior of these "endobronchial sarcomas" affords further indication for separating them from pulmonary spindle cell sarcomas

Fig 8





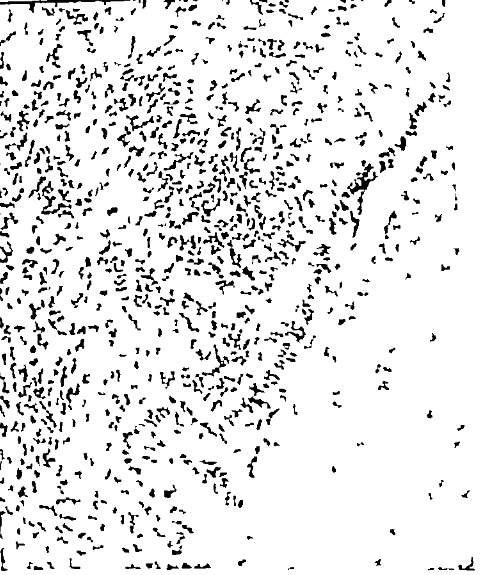


Fig 9

Fig 10

Fig 8 —Endobronchial sarcoma (autopsy specimen) polypoid mass producing bronchial obstruction AFIP Acc 166844

Fig 9 —Endobronchial sarcoma sections deep in the mass reveal neoplastic cells growing in a sarcomatous pattern Hematoxylin and eosin X450 AFIP Acc 166844

Fig 10 —Endobronchial sarcoma necrotic tumor obstructing the bronchus Neoplastic nature of the lesion masked by the secondary inflammatory reaction Hematoxylin and eosin X[illegible] AFIP Acc 166844

TABLE II. ENDOBRONCHIAL SPINDLE CELL SARCOMA CASE REPORTS

AUTHOR YEAR	AGE AND SEX	DURATION OF SYMPTOMS	CLINICAL SYMPTOMS	LOCATION OF TUMOR	GROSS RELATIONSHIP	METASTASES	MICROSCOPIC DESCRIPTION	DEATH OR DURATION
Baum[44] 1938	29 F	1½ mo	Cough, chest pain, weight loss	Right main bronchus	Soft polypoid mass removed by bronchoscopy, x-ray therapy	None	Fibrosarcoma	Died of the 2 yr 9 mo after onset. Squamous metaplasia of bronchus, fibrosis at biopsy site, no tumor remaining
Mass General Hospital[45] 24202 1938	17 F	2 mo	Pleuritic pain, weight loss, cough	Right main bronchus	Mass 1 × 1.5 cm removed by bronchoscopy; thoracotomy attempted	None	Fibrosarcoma "growing at moderate rate" invading bronchial wall	Died of hemorrhage during operation
Pollack[46] 1939	19 M	7 mo	Cough, pain, fever, weight loss, wheezing	Left main bronchus	Soft mass 2 × 3 cm treated by bronchoscopy	None	Fibrosarcoma bronchus	No recurrence after 3 yr
Lewis[47] 1946	14 M	1 mo	Dyspnea, cyanosis, pain, cough	Orifice of right main bronchus up to carina	Soft growth treated by bronchoscopy and x-ray	None	Fibrosarcoma with whorl arrangement and considerable pleomorphism; rebiopsy 3 mo later showed more variation	X-ray normal 2½ yr after onset
Randall and Blades[48] AFIP 166884 1946	30 M	1 yr	Hemoptysis, cough, pneumonia, growing hilar mass. Repeated biopsies "benign"	Right main bronchus	Intrabronchial mass 1 × 2 cm infiltrating wall, largest portion 10 cm just below bifurcation	None	Leiomyosarcoma bronchus	Died at operation of hemorrhage and asphyxia

AUTHOR YEAR	AGE AND SEX	DURATION OF SYMPTOMS	CLINICAL SYMPTOMS	LOCATION OF TUMOR	GROSS RELATIONSHIP	METASTASES	MICROSCOPIC DESCRIPTION	DEATH OR DURATION
Curry and Fuchs[43] 1950	13 F	6 wk	Cough, left chest pain, wheezing, 1 wk before admission, coughed up lump of tissue	Left main bronchus	Gray red mass, 1 5 × 1 cm, smooth gray surface	None	Fibrosarcoma, numerous mitoses, atypical fibroblasts	4 yr, no recurrence
Carswell and Kraeft[42] AFIP 239010 1950	20	18 mo	Left chest pain, dyspnea, cough, small hemoptyses, chills, fever	Left main bronchus	Round, smooth, shining non ulcerated, dark red, fairly firm tumor, treated by bronchoscopy and pneumonectomy	None	Squamous cell metaplasia of bronchus, spindle shaped fibroblasts arranged in loose nests or with no pattern, large hyperchromatic nuclei Pneumonectomy specimen small portion of sarcoma remaining after bronchoscopy	7½ mo P O normal bronchial mucosa
Black[10] 1950	16 F	9 mo	Cough, fever, weight loss, hemoptysis	Basal divisions left lower lobe bronchus	Polypoid, 1 × 5 cm mass, completely occluding bronchus and extending into parenchyma at hilum	None demonstrated at operation	Fibrosarcoma moderately undifferentiated with pleomorphism and mitoses Fine reticulin fibers around individual cells	Died of massive intrathoracic recurrence 6 yr, 5 mo P O

As shown in Table II, one patient remained well four years after the spontaneous expectoration of a "rapidly growing fibrosarcoma" In another, the lungs removed at autopsy showed only *fibrosis at the biopsy site*[48] On the other hand, massive intrathoracic recurrence of another tumor of corresponding histologic appearance resulted in the death of the patient six and one-half years after surgical removal

Other interesting features of this tumor may be discovered by comparing data from Tables I and II

From the figures in Table III it is readily seen that the endobronchial sarcomas, in contrast to those of parenchymal origin, occur more rarely and in younger individuals, are discovered earlier in their development, and in behavior are relatively more benign It may be assumed that any benign or malignant tumor of endobronchial location may easily attract clinical attention, also that parenchymal tumors being "silent" have a much longer preoperative course However, neither do these factors nor the anatomic location entirely explain the remarkable therapeutic results in patients with "fibrosarcoma" of the bronchus, for similar results are not obtained even when small bronchiogenic carcinomas happen to be removed correspondingly early

TABLE III COMPARATIVE DATA FROM CASE REPORTS OF PULMONARY SARCOMA AND ENDOBRONCHIAL SARCOMA

	ENDOBRONCHIAL SARCOMA	PULMONARY SARCOMA
Number of Cases	8	19
Sex		
Male	4	14
Female	4	5
Duration		
Range	6 weeks 18 months	None 7 years
Average	7 months	17 months (14 cases)
Age		
Range	13-46 years	18 65 years
Average	28 years	46 years
Location		
Main stem	7	
Upper	0	4 } 16 cases specified
Middle	0	2
Lower	1	8
Combined lobes	0	2
Right	4	11
Left	4	8
Behavior		
Extrathoracic spread	0	4
Intrathoracic extension or recurrence	1 (after 6 yrs)	3

Whether the data in Table III are the accident *of a small* series, the result of misinterpretation of the histologic criteria for malignancy, or a true indication of differences in behavior will not be clear until there are available larger series with more extensive periods of postoperative observation Until then the trends revealed by these figures justify, at least, clinical separation of the endobronchial sarcomas from intrapulmonary spindle cell sarcoma

Rare Types of Sarcoma of the Lung—There are few reported cases of primary *bronchopulmonary sarcoma other than* those formed by spindle cells of varying degrees of differentiation Examples of "myxoliposarcoma," "chondromyxosarcoma," "myosarcoma" and "giant cell sarcoma" are recorded[49-53] However in these the distribution of the tumor was so widespread that any possible pulmonary origin was obscured or the tumors were so poorly differentiated that the histogenesis was uncertain

Malignant tumors composed of cartilaginous elements are reported with more frequency but they also constitute a poorly defined group[54] Only in one of the recorded cases was a primary origin demonstrated[55] I believe the theory could be advanced that the chondroblastic tissue of the bronchus is the source of the tumor rather than a teratoma or hamartoma, as might be suspected from the example reported by Krienitz[56] In 3,000 primary tumors of the chest filed at the Armed Forces Institute of Pathology, there are no examples of chondrosarcoma in which the tumor is clearly of pulmonary origin

Similar hesitancy is experienced in the acceptance of reported cases of primary rhabdomyosarcoma, an exceedingly rare but important example of pulmonary sarcoma Rhabdomyosarcoma metastatic to the lung may simulate a primary growth both clinically and anatomically, thus obscuring the true origin of the tumor in a distant site or in such neighboring tissues as the heart mediastinum, diaphragm, or upper esophagus[57-59] On record is a rhabdomyosarcoma arising in the pulmonary artery[60]

In its usual form, rhabodomyosarcoma of the lung shares with chondrosarcoma a disposition toward vascular spread, a possible component of several histologic cell types and a tenuous relationship to teratomas or compound tumors in its derivation[61]

When primary development of rhabdomyosarcoma does occur it may be explained as a result of misdirection of the mesenchymal cells investing the bronchial buds as illutrated by Zipkin s[62] case in which the bronchial walls contained striated muscle Dr Edith L Potter, in a personal communication, described a loose network of striated muscle fibers in the pulmonary interstitium of a stillborn infant

These unusual demonstrations of the potentiality of normal cells under abnormal conditions are correlated with the fact that there is only one recorded example of pulmonary rhabdomyosarcoma of unitary cell type[63] The Chest Tumor Registry also contains one example of well-differentiated rhabdomyosarcoma in which the certainty of a primary pulmonary origin was weakened by an apparent collision in one area with an epidermoid carcinoma of the esophagus

This tumor is of greater importance than its extreme rarity indicates because it is often considered in the differential histologic diagnosis of certain types of bronchiogenic carcinoma[64, 65]

DIFFERENTIAL HISTOLOGIC DIAGNOSIS

The imitators of bronchopulmonary sarcoma that are most frequently confused with the true primary tumors are "oat cell carcinoma[6] postinflammatory repair[7, 8] and pleomorphic cell carcinoma of the bronchus[65, 66]

When a peripheral sarcoma encroaches upon a bronchus, it may in the biopsy specimen resemble undifferentiated cell carcinoma of the bronchus ("oat cell" or "reserve-cell" carcinoma) (Fig 2) The diagnosis is of great importance since the epithelial tumor, according to statistics from the Armed Forces Institute of Pathology, is 500 times as common and is more rapidly fatal to the patient The frequent diagnosis of sarcoma of the lung in the medical literature may be the result of confusion of these two tumors Reticulum stains are especially useful in differentiation, since the reserve cell carcinoma was shown in the course of this study to produce no stainable reticulum and each sarcoma, stained at the same time, displayed small or large amounts of this material (Fig 4)

In other instances inflammatory reactions in the bronchus or pulmonary parenchyma may stimulate such proliferation and repair as to produce a tumor resembling true neoplasia Brown and Johnson[67] have recently described this process in the pleura resulting from poorly resolved, localized exudate Somewhat similar examples have been previously reported in the lung,[24, 69-73] and four cases have been more recently described[68] These, like the peripheral sarcomas, may be well-circumscribed, firm, white, and slow growing However, they are usually smaller than sarcomas, and the admixtures of inflammatory cells, together with bits of bronchiolar epithelium which may be attracted to the mass, serve to distinguish the puzzling fibroblast as reactive rather than neoplastic Differentiation may be impossible when portions of the "inflammatory tumor" are composed solely of fibroblasts, colonizing in whorls and duplicating a fibrosarcoma

The endobronchial sarcomas are among the most difficult to diagnose Not only may the neoplastic process be masked by secondary inflammation but when biopsy of a small polypoid tumor does reveal a sarcomatous pattern, the pathologist may not be certain whether the tumor is a true sarcoma or an epidermoid carcinoma showing spindle changes (Fig 12) Ackerman[74] recently described four cases of the polypoid tumor designated "carcinosarcoma" by him and "sarcomatoid carcinoma" by others[75] This polypoid compound tumor is slow growing, of relatively low malignancy, and its behavior is more like that of true endobronchial sarcoma than like that of orthodox examples of bronchiogenic carcinoma (Fig 12) Although differentiation may be of only academic importance it can be made in some instances by multiple sections showing clearly squamous epithelium in transition to *sarcomatous structures* (Fig 13)

Although reported examples of rhabdomyosarcoma are extremely rare, their importance lies in the fact that they may be confused with pleomorphic cell carcinoma[65, 66] In this type of bronchiogenic carcinoma the neoplastic cells become dissociated and bizarre imitating the large "plasmodial" giant cells described as a *variant of rhabdomyosarcoma*[76, 77] The differentiation of the two tumors is of both therapeutic and prognostic significance, for a study of nine examples of pleomorphic cell carcinoma reveals that this tumor tends to achieve a large bulky growth which, by virtue of its relentless local extension or distant metastasis kills the patient more swiftly Search for cross striations

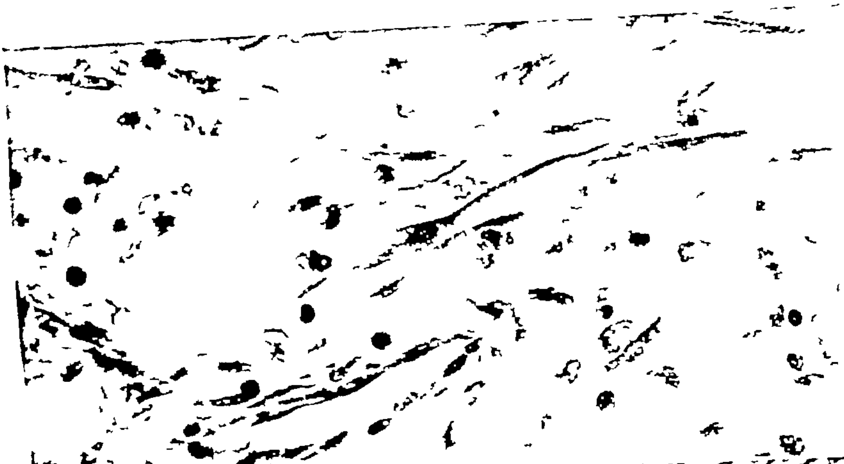


Fig 11

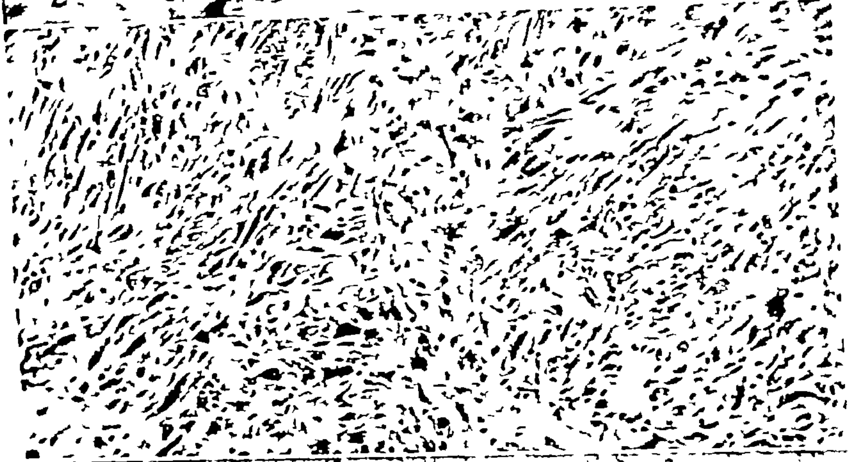


Fig 12.

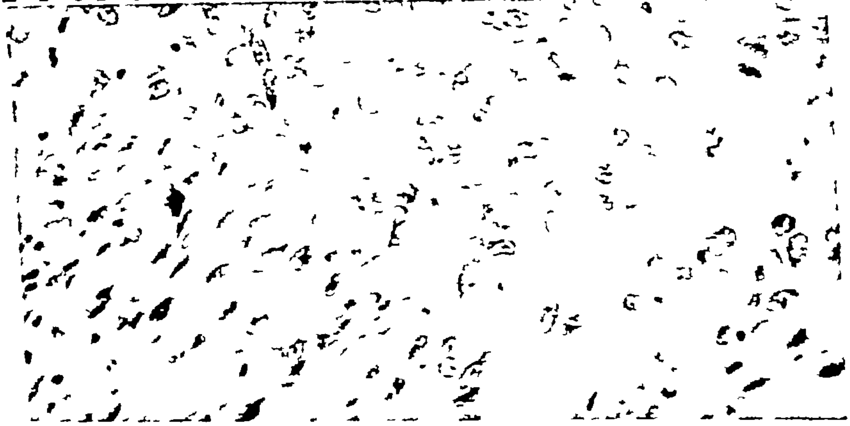


Fig 1

Fig 11—Endobronchial sarcoma biopsy specimen from intrabronchial mass showing fibroblasts macrophages and inflammatory cells Hematoxylin and eosin ×450 AFIP Acc [illegible]

Fig 12—Sarcomatoid [illegible] carcinoma of bronchus Hematoxylin and eosin ×125 AFIP Acc [illegible]

Fig 13—Sarcomatoid [illegible] carcinoma of bronchus The sarcomatous appearance of large portions of the tumor is confusing until serial sections show transitions with areas of squamous epithelium (see Fig 12) Hematoxylin and eosin ×27[illegible] AFIP Acc 260561

or for fibers impregnated with silver may aid in distinguishing the two tumors If these features are absent, multiple sections of these bizarre giant cell tumors will usually reveal mucus production, abortive gland formation, or syncytial patterns, which aid in the accurate diagnosis of the tumor as "carcinoma "

SUMMARY AND CONCLUSIONS

1 The cases reported here are acceptable as pulmonary spindle cell sarcoma on the basis of clinical and morphologic evidence This tumor is most frequently a well-circumscribed neoplasm, composed of immature spindle cells, it occurs in middle life, is of relatively long duration, and metastasizes in approximately one-third of the cases

2 Sarcoma in the proximal bronchi differs from sarcoma of parenchymal origin in that it occurs even more infrequently, affects chiefly young adults, is relatively less malignant in behavior, and is usually shown to be composed of mature fibroblasts

3 Other types of mesodermal sarcomas, such as liposarcoma, rhabdomyosarcoma and chondrosarcoma are so very rare that only isolated examples have been reported

4 The accurate morphologic diagnosis of bronchopulmonary sarcoma is complicated by its more frequent imitators These are (a) undifferentiated cell bronchogenic carcinoma, which may be distinguished from poorly differentiated pulmonary sarcoma by reticulum stains, (b) postinflammatory fibroblastic repair simulating neoplasia and resembling well differentiated pulmonary sarcoma, (c) polypoid epidermoid carcinoma with sarcomatoid differentiation, which in behavior and in structure may imitate endobronchial sarcoma, and (d) pleomorphic cell carcinoma of the bronchus, which is often diagnosed myosarcoma or rhabdomyosarcoma

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EXPERIMENTAL PRODUCTION OF PROGRESSIVE PULMONIC STENOSIS

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TO DATE no one has described an ideal method for the gradual occlusion of a large vessel wherein the degree of occlusion present at a given time could be predicted, this lack occurs in spite of the facts that the problem has attracted attention for many years and that a variety of methods have been employed in pursuit of this goal. Reports on the use of metal bands,[1] fascial strips,[2] ligatures of cotton or silk,[3] the excision of part of the vessel wall,[4] and the application of dicetyl phosphate[5] or of Cellophane film[6] are found in the literature, various degrees of success have been claimed for the respective methods

In our laboratory, the method of wrapping of large veins with bands of Cellophane has been used routinely to produce gradual obliteration of the lumina of vessels, others[7] have reported progressive narrowing of the thoracic or abdominal aorta in dogs by use of similar methods Results of the application of such bands to the main pulmonary artery or around the outflow tract of the right ventricle in dogs form the subject of this report

METHODS

In the first group of animals, the Cellophane was applied around the main pulmonary artery in its middle third An incision was made in the left side of the thorax between the fourth and fifth ribs The pulmonary artery was thus exposed and was completely freed from its attachment to the aorta by sharp dissection close to the pulmonary arterial wall One or two laminated Cellophane bands, 6.5 mm in width, were placed completely around the vessel In the first two dogs in this group, the band simply was fitted snugly around the artery, but in subsequent operations it was tightened so as to obtain an initial reduction of the lumen estimated to be 50 per cent of the original cross sectional area Following this procedure and after a period of observation of the heart's action, the pericardium was closed and the thoracic wall restored in layers

The same methods of approach and closure were used in the animals of the second series, but in this group of dogs a tunnel was formed by dissection beneath the pericardial fat pads that occupy the region of the fibromuscular junction of the pulmonary artery and right ventricle Two or three Cellophane bands were passed through this tunnel so as to encircle completely the pulmonary artery, again, an estimated 50 per cent reduction of the lumen was sought By this method the bands were secured in position at the ring of the pulmonary valve and were prevented from riding up the artery

In the final group of animals, an attempt was made to produce subpulmonic stenosis A midsternal incision was made in the thorax and the heart was cradled by pericardial stay sutures A finger was inserted into the cavity of the right ventricle through a stab wound made approximately 6 cm below the ring of the pulmonary valve With this finger utilized as a means of control, a long slightly curved needle was driven through the interventricular septum 1.5 to 2 cm from the pulmonary valve and made to emerge beneath

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the right coronary artery 1 to 1 5 cm from the ring of the valve A Cellophane band, 6 5 mm in width, was attached to the needle and pulled through the interventricular septum The band was then threaded across the lateral aspect of the wall of the right ventricle in a series of short bites until the original point of entrance was reached The band was tied under some degree of tension and the knot secured with a cotton ligature The pericardium was closed with interrupted sutures and the thoracic wall restored

Preoperative roentgenograms and electrocardiograms were obtained, and these studies were continued in the postoperative period Catheterization of the right side of the heart was performed at intervals throughout the time of observation, the pressures were recorded by means of a saline manometer In some animals, the final readings were obtained by means of a strain gauge galvanometer system similar to that described by Wood[8]

RESULTS

Placing the Cellophane bands at operation was not without hazard, instances were encountered in which a tear was occasioned in the thin-walled pulmonary artery Experience demonstrated that freeing of the vessel was accomplished best by dissection with sharp scissors in the plane of tissue between the arterial wall and its overlying fibrofatty tissue, aided by blunt dissection during which the points of a right-angled gall bladder clamp were worked against the tip of the finger Also, it was not easy to judge the correct amount of initial constriction, overzealous immediate tightening of the band resulted in death from excessive obstruction to the outflow of the right ventricle

Instances of what might be interpreted as pulmonary vasoconstriction were encountered in two dogs During dissection, the pulmonary artery suddenly decreased greatly in size, this was followed quickly by ballooning of the right ventricle and a noticeable slowing and weakening of cardiac action This state was maintained for three or four minutes, when an equally sudden return of the pulmonary artery to its previous size occurred, accompanied by rapid disappearance of the right ventricular dilatation and resumption of normal cardiac action One of these two dogs was found dead the morning after operation, findings at necropsy were indicative of acute obstruction to outflow from the right ventricle

It was noted also that only one or two bands should be placed If more than this number were applied, they combined to form a hard, unyielding ring that ultimately eroded through the wall of the pulmonary artery

PULMONIC STENOSIS

Studies of Pressure —The dogs in the first group were catheterized twice, once within a month of operation and again just prior to death The results are given in Table I Right ventricular hypertension was demonstrated in two of four surviving dogs These two animals were among those in which initial reduction in the lumen of the pulmonary artery had been obtained Pressures in the pulmonary artery distal to the band, in the right auricle, and in the inferior vena cava were within normal limits

The animals in the second group were catheterized more frequently, the results are listed in Table II Two dogs showed slight increase of right ventricular pressure early in the postoperative period, but a progressive increase

TABLE I MEAN BLOOD PRESSURES IN 4 DOGS AFTER SIMPLE PLACEMENT OF CELLOPHANE BANDS AROUND PULMONARY ARTERY

DAYS P O	PRESSURES, MM OF MERCURY				REDUCTION IN LUMEN, PER CENT	HYPERTROPHY
	INFERIOR VENA CAVA	RIGHT AURICLE	PULMONARY ARTERY	RIGHT VENTRICLE		
240	3	4	20	39	76	Present
210	4.4	7	*	46	81	Extensive
212	2.2	0.6	*	13	40	Present
224	3	0.9	16	13	39	Absent

*Unable to pass catheter into pulmonary artery

was revealed during later studies Right ventricular hypertension was present finally in three of the four dogs in this group, again, pressures in the pulmonary artery and right auricle remained within normal limits No evidence was noted of elevation of the end-diastolic pressure in the right ventricle One of the animals which exhibited increased pressure in the right ventricle early in the postoperative period was found dead on the nineteenth postoperative day, the wall of the pulmonary artery had been eroded by the constricting Cellophane band

TABLE II MEAN BLOOD PRESSURES (EXCEPT WHERE INDICATED) IN 4 DOGS AFTER ANCHORING CELLOPHANE BANDS AROUND PULMONARY ARTERY

DOGS	DAYS P O	PRESSURES MM OF MERCURY				REDUCTION IN LUMEN, PER CENT	HYPERTROPHY
		INFERIOR VENA CAVA	RIGHT AURICLE	PULMONARY ARTERY	RIGHT VENTRICLE		
1	16	9	6	17	35		
	57	7	6	19	34		
	117	–	4/–1	18/10	95/1	77	Present
2	22	4	1	13	14		
	64	2	0.7	11	15		
	93	6/2	5/1	24/8	60/1	63	Slight
3	12	14.5	14.5	34	26	Pulmonary artery eroded by band	Present
4	13	4	1.5	18	14		
	37	2.6	1	21	20		
	97	–	–3/–5	30/12	29/–3	64	None

Electrocardiograms.—No changes were observed in postoperative records until the third day At this time slight elevation of the S T segment was noted in Leads I, II, III, and aV$_F$ and depression of the S-T segment of equal magnitude was present in leads aV$_R$ and aV$_L$, these changes were accompanied by an increase in the amplitude of the T wave in all leads These alterations progressed to a maximum on the seventh day when the shift of the S-T segment was well defined and the size of the T wave was equal to or exceeded that of the QRS complex From this point the modifications regressed until, on the seventeenth postoperative day the S-T segment was again on or near the base line and the T wave was the same size as that in control records Beginning at this time gradual alterations of the QRS complex were noted the most prominent features being an increase in depth of Q_I S_{II} and S_{aVF} with increase in height of R_{aVL} and decrease of S_{aVR} These variations progressed to produce final records that were greatly different from control records, a mainly negative deflection being noted in Leads II and aV_F, while aV_R had become wholly positive A biphasic deflection of approximately equal negative and positive components was recorded from Leads III and aV_L. In these last records, a positive shift occurred in the S-T segment in Leads II, III, and aV_F, with an accompanying negative displacement in lead aV_R No significant alteration was noted in the duration of the QRS interval at any time during the period of observation An example of these changes in configuration of the QRS complex is seen in Fig 1

Animals in which right ventricular hypertension did not develop yielded postoperative records similar to those obtained during the preoperative period

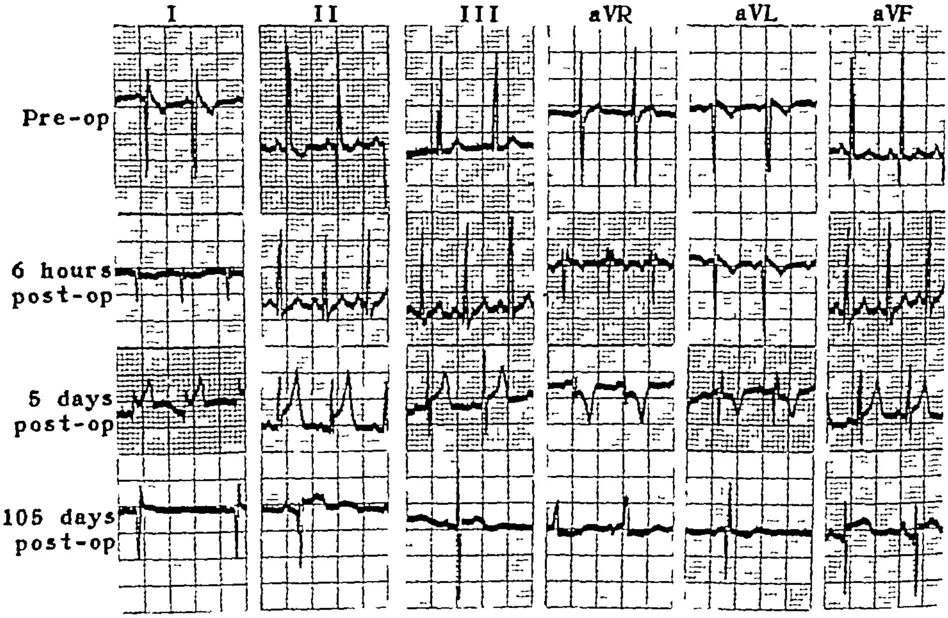

Fig 1 —Electrocardiographic changes during development of right ventricular hypertension.

Roentgenograms—In only one dog was any evidence of cardiac enlargement obtained by roentgenologic examination In this animal, slight enlargement of the cardiac shadow was seen toward the end of the first month, definite evidence of increase in size was present at the beginning of the third month The records were made with the animal in the anteroposterior position and the increase in size of the cardiac shadow was noted along the lateral border of the right ventricle This animal exhibited the greatest right ventricular pressure recorded in this study

Necropsy and Histologic Findings—In all dogs the Cellophane bands were buried in a mass of firm, fibrous tissue that was adherent to neighboring structures Although this connective tissue was applied closely to the Cellophane, it was not adherent to the bands and they could be extracted from their beds with little difficulty. Apart from being somewhat more brittle than before the bands were unaltered grossly. In the first series of animals the bands had moved toward the bifurcation of the pulmonary artery, so that compression of the right and left branches was present at their origin, rather than compression of the main pulmonary trunk. In the second group of animals the original placement essentially was maintained. In all instances the cross sectional area of the lumen of the vessel was reduced at the point of application of the band; measurement of this constriction revealed that only when the lumen was reduced by at least 63 per cent of its original size was right ventricular hypertension present. One exception was noted: one dog which had no evidence of right ventricular hypertension on catheterization and which had a luminal reduction estimated at 40 per cent had hypertrophy of the right ventricle at necropsy.

The pulmonary artery beneath the band usually appeared normal grossly although it was thinner than in immediately adjacent parts. Small ridges of endothelium were present at the point of greatest constriction in two dogs which had hypertension. In addition, an oval aneurysmal area 1 by 0.5 cm was found in one of these dogs; this aneurysmal change was situated in the posterior wall of the pulmonary artery approximately 2 or 3 mm on the right ventricular side of the bands. Prestenotic or poststenotic dilatation of the pulmonary artery was not found in any animal.

In dogs displaying hypertension, the right ventricle was enlarged and overhung the left so that the length from base to apex was equaled by the widest diameter. Measurements of the width of the muscle of the right ventricle demonstrated an increase in the muscle mass of the hearts of hypertensive dogs when compared to hearts of normal dogs or of those in which hypertension did not develop (Fig. 2).

Histologically, compression and atrophy of the pulmonary arterial wall were noted beneath the band associated with a subendothelial increase in connective tissue elements especially on the right ventricular side of the constriction. No alteration was found in the endothelial lining throughout the main pulmonary vessels.

SUBPULMONIC STENOSIS

In no instance was evidence of right ventricular hypertension or hypertrophy found in dogs which had subpulmonic stenosis, nor had the encircling cellophane band produced any obstruction to outflow from the right ventricle. The bands were found encased in a small rim of dense fibrous tissue sharply defined from the surrounding muscle; in only one animal was the band found to be broken. One dog exhibited a small outpouching of the wall of the right ventricle between the band and the ring of the pulmonary valve, but catheterization studies revealed no obstruction to outflow from the ventricle.

Microscopic examination of the parts through which the bands had passed revealed that an encircling ring of densely packed, practically avascular, collagenous fibers had been laid down around the band This layer of fibrous tissue was distinct from the adjacent cardiac muscle, which exhibited no abnormal features

COMMENT

Though the series studied was relatively small, points of technique contributing to success or failure were carefully considered in each case It was

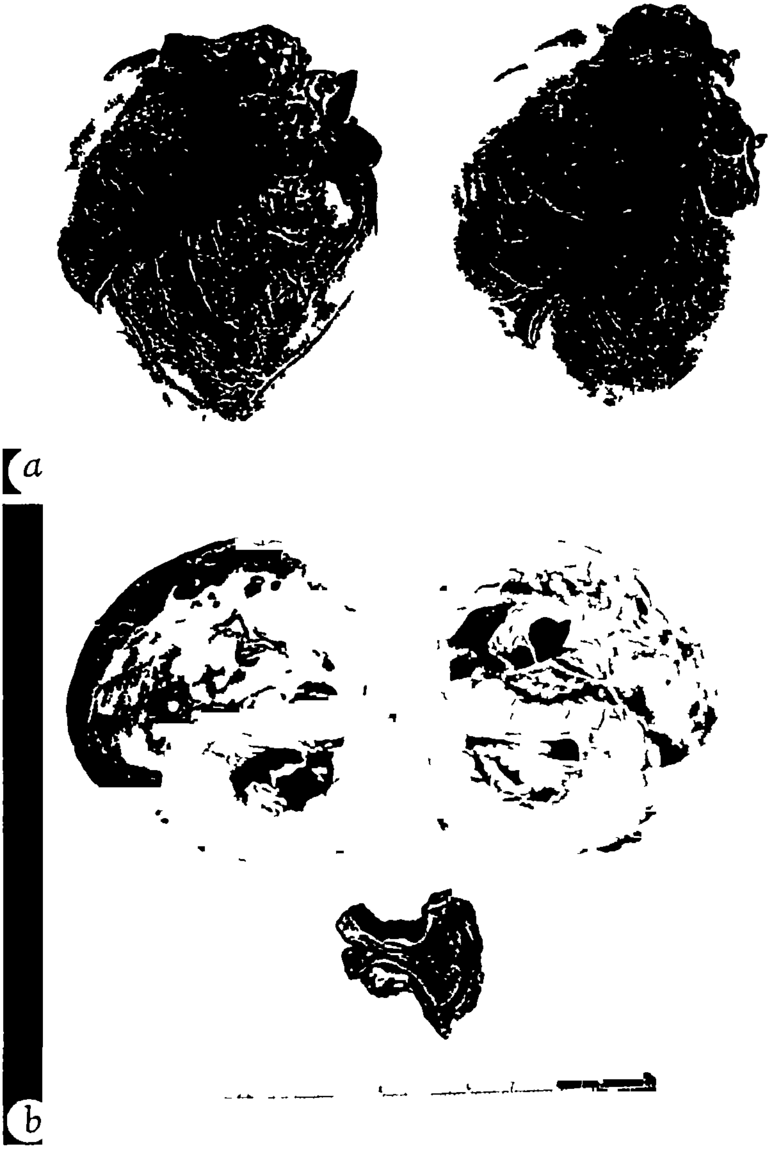

Fig 2 —a Anterior view of hearts The specimen on the left was from a dog which did not exhibit right ventricular hypertension that on the right was from an animal which exhibited a mean right ventricular pressure of 46 mm of mercury b cross section of a heart from a dog which had right ventricular pressure of 95/1 expressed in mm of mercury note dilatation and hypertrophy of the right ventricle and the degree of stenosis of the pulmonary artery

considered that the major factor in eventual production of right ventricular hypertension resided in the degree of initial constriction produced at operation. If this was insufficient, the later stricture did not offer enough resistance to outflow from the right ventricle to promote hypertension, while if it was too severe the right ventricle was unable to maintain circulation against the excessive load. Gibbon and co-workers[9] have shown that the cross-sectional area of the pulmonary artery may be reduced by approximately 60 per cent before hemodynamics are altered. On the basis of this and other work,[10] the figure of 60 per cent was used as the point of initial constriction in this series, but unfortunately no method was available to insure that this degree of narrowing was obtained in all cases.

That the stenosis was of a progressive character was evidenced by results of the catheterization studies. Records obtained soon after operation were similar to control records; several weeks passed before a substantial increase in right ventricular pressure was noted. It was interesting to find that even in a dog which demonstrated a right ventricular systolic pressure of 100 mm. of mercury no elevation was found in the end-diastolic pressure, while the pressures within the right auricle and the venae cavae remained within normal limits. This situation denotes that the ventricle had fully compensated for the increased resistance to outflow. This compensation was accomplished in all cases without the development of a gross degree of muscular hypertrophy. Similar findings were reported by Holman and Beck,[11] who noted that an increase in flow was a more potent stimulus to cardiac hypertrophy in animals than was resistance to outflow. All dogs showed a decrease in pressure across the region of stricture; the degree of stenosis was paralleled by the amount of right ventricular hypertension.

No immediate electrocardiographic changes of importance were noted after the bands were placed around the pulmonary artery, but later observations revealed two interesting periods of change. During the first period, which lasted from about the third to the seventeenth postoperative day, electrocardiographic findings were compatible with those of right ventricular strain as described by Goldberger.[12] It is possible that the early and vigorous reaction of tissue to the presence of Cellophane produced a temporary stricture of the pulmonary artery that was sufficient to embarrass the right ventricle; then as the early changes of inflammation regressed, the lumen again widened sufficiently to cause little resistance to outflow from the right ventricle. Unfortunately, no studies of pressure were made during the acute phase of this period. The second phase commenced during or shortly after the terminal stage of the first, and the major changes were noted in Leads II, III, aV_R and aV_F. These alterations consisted of almost complete reversal in direction of the major QRS component in each lead and were progressive from week to week, finally becoming stabilized between the seventieth and ninetieth day. Comparison between similar leads from these hypertensive dogs and from a 1[illegible]-month-old greyhound that had congenital pulmonic stenosis and extensive hypertrophy of the right ventricle demonstrated a close resemblance among the records The thoracic leads in each instance fulfilled many of the criteria necessary for the electrocardiographic diagnosis of hypertrophy of the right ventricle in man [13]

Histologically, thinning and atrophy of the pulmonary arterial wall were noted beneath the band, together with an increased amount of subendothelial connective tissue mainly on the central but also on the peripheral side of the region of stenosis In one dog, a small area of erosion was noted in the arterial wall, presumably caused by turbulent flow created by increased resistance Otherwise no extensive changes occurred in the pulmonary artery

SUMMARY

Wrapping of Cellophane bands around the pulmonary artery in dogs resulted in right ventricular hypertension and hypertrophy of the right ventricle The major factor contributing to a successful end result was thought to be the initial degree of constriction produced at operation

Results of cardiac catheterization and of electrocardiographic studies were indicative of the progressive nature of the stenosis

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LUNG ABSCESS AND BRONCHIAL CATHETERIZATION

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I. BRONCHOGRAPHY BY CATHETERIZATION IN LUNG ABSCESSES

WE SHALL deal only with lung abscesses apparently due to no pre-existing lesions, such as bronchial carcinoma, neighboring bronchiectasis, hydatid cyst, etc.

It is customary to say[26, 28, 34] that bronchography does not inject the cavity of such abscesses. That is true as far as the classical techniques of bronchial opacification are concerned. On the other hand it is possible to obtain satisfactory opacification of lung abscesses by injecting the contrast medium by means of a catheter into the diseased lobe or segment. We deem such a procedure to be highly profitable since it gives us an accurate anatomic picture of the lesions at the beginning of treatment; adequately localized antibiotic instillations are thereby made possible. At the end of treatment it contributes to the correct appreciation of the final results. Applied to a whole series of lung abscesses it enabled us to get a clearer picture of their anatomic evolution and in particular to make apparent the remarkable frequency of residual cavities.

We shall successively deal with our equipment, the technique of accurate bronchography in abscesses, and the subsequent results.

EQUIPMENT

The catheters (Fig. 1) that we use* are made of rather stiff rubber. The end of the catheter is made opaque by the addition of lead salts. They allow a deeper and more accurate penetration into the bronchial tree than Thomson's catheter. They come in two diameters: No. 19, the larger of the two, convenient for aspirations and total bronchography with water-soluble medias, and No. 15, the smaller, which is used in most cases.

Different types of catheters may be obtained: *Straight catheter. Curved catheter* whose end makes an angle of approximately 100 degrees with the body. This type of catheter is most often used; in total bronchography it makes it possible to switch rapidly from the right to the left side, and its extremity lodges easily at the entrance of the upper lobe bronchus. It is also used for the middle lobe and the various segments of the lower lobe (with the exception, however, of the apical segment). *Strongly curved, hook shaped catheter* convenient for catheterizing the apical segment of the upper lobes. *Catheters with a double bend* necessary to penetrate the posterior and anterior segments of the upper lobe and often quite useful to enter the bronchus leading to Nelson's lobe. For instance, the same catheter will be used for the posterior segment

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*Designed by H. Métras and manufactured by the firm Gentile in Paris.

of the right upper lobe, for the lingula of the left upper lobe, and for the apical segment of the right lower lobe.

A sensible choice of sound plays a considerable part in the final success. Several attempts are sometimes necessary to hit upon the right type of sound. In some cases, no sound has the curve necessary and it must be modified for the case in question.

Before finishing we would like to point out the ingenious little instrument, devised by Pieri and Casalonga.[6, 7] It is a catheter whose tip can be directed and which can render real service in the catheterization of segments difficult to enter (in particular the apical segment of the superior lobe). Gidlund of Stockholm suggested the use of a similar catheter.

A steel mandrel is used to guide the catheter down to the glottis.

A conical adaptor, because of its cylindrical grooves, allows a satisfactory tightness of the syringe-sound group.

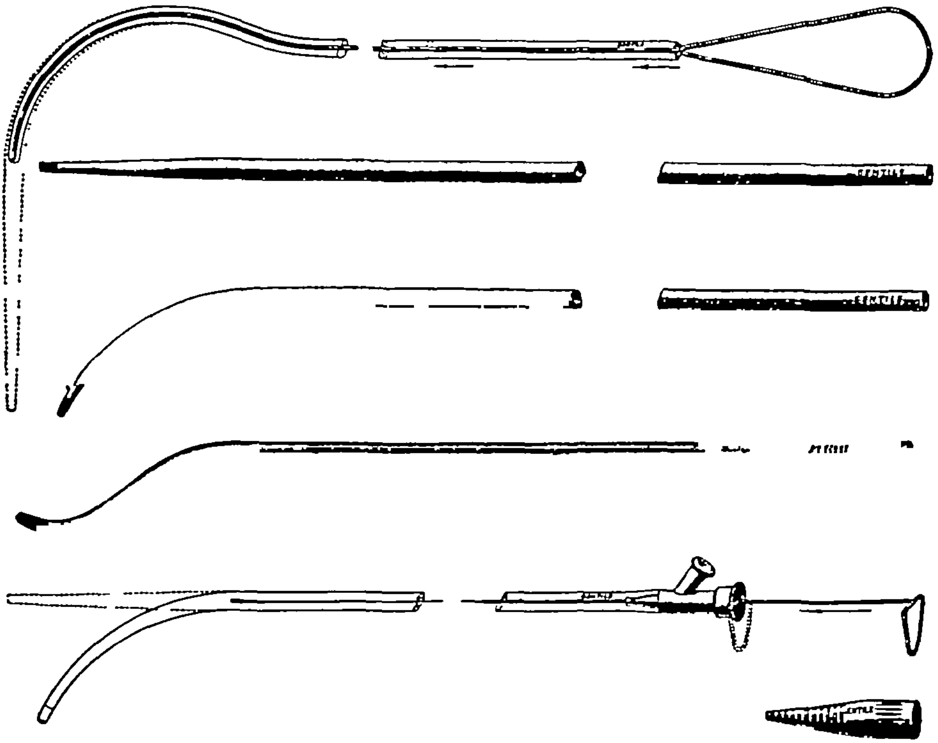


Fig. 1.—Equipment from top to bottom: the sound on its mandrel, a straight catheter, a curved catheter, a double curved catheter, another type of mandrel, the conical adaptor.

TECHNIQUES

A. *Anesthesia.*—We use a preanesthesia: 0.20 Gm. gardenal and 0.5 mg. atropine one half an hour before the examination, then a 1 per cent solution of Pantocaine above the larynx and a 0.5 per cent solution in the bronchial stage

The use of a Vilbiss atomizer allows a notable saving of drugs in the bucco-pharyngo laryngeal stage The total dose of Pantocaine used must not exceed 0 001 Gm for each kilogram of weight If this rule is adhered to and if barbiturates are used as preanesthetics, toxic accidents are negligible

B Catheterization —When the anesthesia is complete the patient is made to strip to the waist The selected catheter is slipped over the guiding mandrel previously lubricated with Lipiodol (we make sure that the catheter moves freely along this mandrel) then with the help of a laryngeal mirror the end of the catheter is placed at the entrance of the larynx All we have to do then is slip the catheter off the mandrel while holding the latter in position When the passage of the sound is difficult, as in the cases of catheters with double curves it is advisable to push the catheter beyond the glottis with the help of the laryngeal mirror, in this instance the catheter should be pushed in by an assistant

Before leaving the site of anesthesia, we make sure that the catheter is correctly placed in the trachea (One is relatively sure it is well placed if the catheter can be moved freely, the patient can no longer talk)

The patient is then requested to close his mouth and hold the catheter in his fingers as he would a cigarette The remaining procedure is conducted under fluoroscopic control by means of small back and forth and revolving motions, the end of the catheter should be introduced into the lobe or the segment to be catheterized For this procedure the diaphragmatic opening should be very small so that clear front and lateral view of the end of the catheter may be obtained Once the catheter is placed, the anesthesia is completed with an injection of 1 c c of a 0 5 per cent solution of Pantocaine

C Bronchography —The patient's position is of little importance if a cavity has to be injected since the catheter blocks the return of the Lipiodol, and the examination can be made with the patient standing behind the screen If a more extensive bronchography is desired, for example, that of a whole upper lobe we of course, must take into account the laws of gravity and operate while the patient is in a lying position

The most classical contrast medium is a 40 per cent solution of Lipiodol but, in those localized bronchographies which are performed in order to inject abscess cavities we are much in favor of water soluble drugs of the Ioduron B,[11] [16] [33] Umbradyl,[2] [23] or Diodone[5] [24] type, whose advantages we have pointed out[4] Such drugs make possible repeated opacifications of the cavity without undesirable residual shadows Moreover, Diodone extremely irritating in total bronchography is in this case injected through the trachea and the larger bronchi that is through the most sensitive parts of the bronchial tree by means of the catheter which makes it perfectly tolerated

With this technique it is possible to inject though sometimes after a few failures nearly all lung abscess cavities The catheter never penetrates the cavity proper it blocks up its draining bronchus and the opaque medium injected penetrates wholly or nearly so, the suppurative lesion

DATA OBTAINED BY BRONCHOGRAPHY IN LUNG ABSCESSES

Bronchography must be done at the beginning and at the end of treatment of lung abscesses in order to be able to appreciate the quality of the healing

A Initial Bronchography—It presents numerous advantages as Mattei clearly pointed out It definitely localizes the involved segment It makes possible an accurate anatomic picture of the suppuration to be treated In some cases, Lipiodol shows lesions that standard x-ray examinations do not at all disclose, for instance, it outlines one of those fistulas created by parenchymatous suppurations between two segments, or even through an interlobar fissure Such communications prove particularly frequent between the diverse axillary zones

For the physicians who treat abscesses with instillations, initial bronchography assures a still more valuable function the contrast medium shows the antibiotic its way The practitioner knows that if he uses the same catheter held in the same position, he will safely inject penicillin, Aureomycin, or Chloromycetin into the abscess

It is often advisable with a patient suffering from acute suppuration to postpone a few days such an examination As soon as he is hospitalized, we submit such a patient to a systemic antibiotic treatment penicillin, or even better Iodhydrate of the diethylaminoethylic ester of benzyl penicillin, Aureomycin or Terramycin, according to the bacteriologic data We immediately perform a bronchoscopy, this examination enables us to spot which segmentary opening exudes pus, to get bacteriologic samples in situ and to cleanse the diseased opening with adrenalin The radiologic file has in the meantime been established with a good lateral film as the master document We then proceed to make a first instillation which enables us to select the appropriate catheter, and one or two days later we perform our initial bronchography

If Lipiodol is applied, we shall use a small dose, 5 c c at most, so as not to interfere with later radiologic examinations, but, as we have pointed out, it is better to apply diodone to such cases, the images obtained are a little less spectacular (Figs 2, 5, 9, and 10) but the advantage of an *instantaneous* resorption is very great in the case of an affection that will have to be watched daily under x ray examinations

B Final Bronchography—We deem this step to be of a still greater importance than the initial examination It is indeed necessary to make another anatomic checkup at the end of the treatment (whatever the technique used) Bronchography often gives more accurate results than tomography, as Case 1 shows

Case 1—A tanner, 48 years old, after one week of fever in January, 1951, expectorated a small quantity of putrid sputum He was hospitalized on Jan 15, 1951 He expectorated 150 Gm of pus daily X ray findings included a large cavity *in the* posterior segment of the right upper lobe After 38 days of systemic penicillin treatment, *one million units daily (no local treatment)*, there was clinical and radiologic recovery Tomographies taken on Feb 27, 1951, showed a small suspicious image within 8 cm of the posterior aspect On March 5, 1951, a diodone bronchography showed a residual cavity in the posterior segment of the right upper lobe (Fig 2) The patient was discharged under observation.

In the final bronchography, there are fewer inconveniences to the use of Lipiodol and it is often interesting to pull back the catheter into the main bronchus after a local injection of the diseased region, in order to make a complete opacification of the diseased lung so as to verify the soundness of the whole bronchial tree

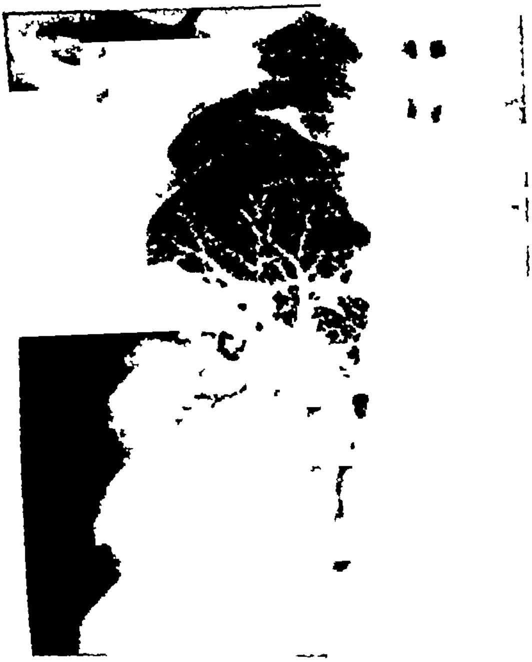


Fig 2 (Case 1)—Abscess of the posterior segment of the right upper lobe treated by systemic penicillin clinical healing Bronchography at the end of the treatment showed small residual cavity

At the end of a treatment, bronchography may reveal a *strictly normal* bronchial tree, on the other hand it often makes apparent *residual lesions* bronchial dislocations and distortions small local bronchiectasis, and especially residual cavities at the site of the suppurative lesion When careful bronchographies are performed on patients clinically "healed" of their lung abscess residual cavities are frequently discovered We were impressed by the fact that such cavities are often quite well tolerated provided they are of small volume and in a location allowing drainage We have nine patients under observation who have been clinically healed for more than two years in spite of considerable anatomic sequelae revealed at the end of the treatment Cases 2 and 3 are of such a type

Case 2—A 55 year old market fishmonger, an obese woman, was without any respiratory incident On April 27, 1949, she presented an acute pneumonitis with an abrupt beginning She was hospitalized on May 10 1949, in a serious condition which made any immediate local intervention inadvisable Under systemic penicillin treatment the patient's general condition improved but purulent expectoration and radiologic symptoms persisted The first instillation was made on June 1, 1949 Bronchography performed after the fifth instillation showed a large bilocular cavity in an axillary branch of the anterior segment of the right upper lobe Eight more instillations of one million units penicillin were given At the beginning of July, the clinical recovery was complete The patient left the hospital, she was examined again on Jan 24, 1951 Clinical recovery persisted, and the standard film was normal

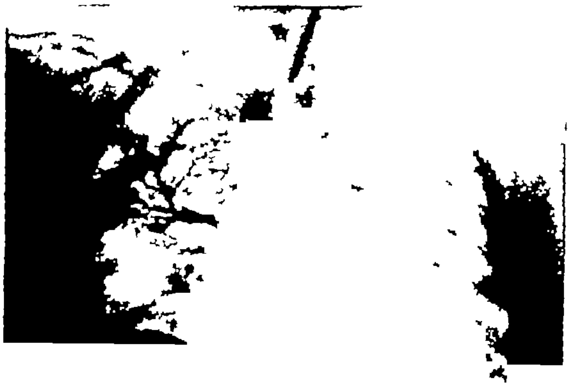


Fig 3 (Case 2) —Lipiodol bronchography six weeks after clinical healing small residual cavity

In Case 2, we have been unable to establish what became of the residual cavity by means of a later bronchography On the contrary, the interest in Case 3 lies in the fact that segmentary Lipiodol still revealed a residual cavity in a patient who has been well for over two years

CASE 3 —L A Z, 56 years old, was hospitalized in November, 1948 An abscess in the posterior segment of the right upper lobe showed marked improvement after nine instillations of 400,000 units of penicillin On Feb 8, 1949, bronchography revealed a residual cavity and bronchial irregularities After six more instillations there was clinical healing The patient was examined again in May, 1951, and there was no respiratory manifestation since the patient's abscess However, the bronchography performed on May 23, 1951, showed two very small residual cavities in the posterior segment of the right upper lobe (Fig 4)

Obviously there are less favorable cases where either large or poorly drained cavities precipitate a relapse of the suppuration Here again, bronchography gives an accurate surgical orientation as Case 4 demonstrates

CASE 4 —D U R, a 45 year old salesman, had an abscess in the apical segment of the right upper lobe in May, 1950 Healing occurred after local penicillin treatment, yet a huge cavity persisted which was easily injected with diodone (Fig 5) The location of the cavity as well as the patient's rather poor general condition made resection inadvisable at this time Relapse occurred in January, 1951, a total diodone bronchography injected no cavities however, an accurate bronchography performed with Pieri's catheter revealed a large residual cavity Lobectomy was performed after cleansing instillations (Dr Reboud) Histologic examination revealed a nonepithelized intraparenchymatous cavity

CONCLUSIONS

In the treatment of lung abscesses accurate bronchography using preferably a water-soluble contrast medium, yields valuable information on the size and the exact location of initial lesions as well as on the amount of anatomic healing

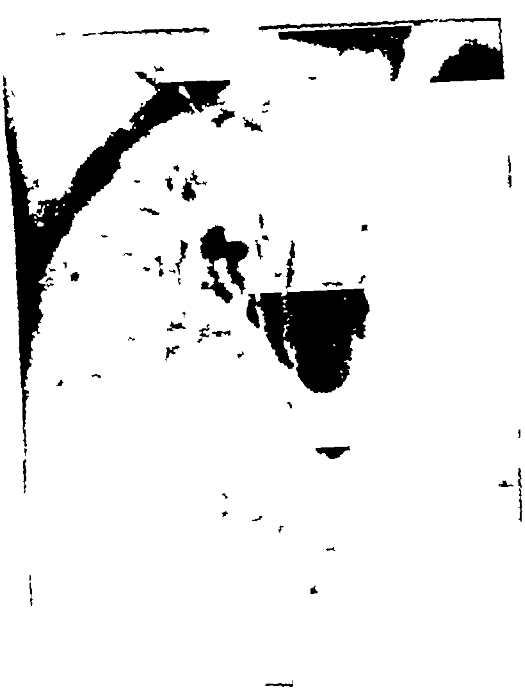


Fig 4

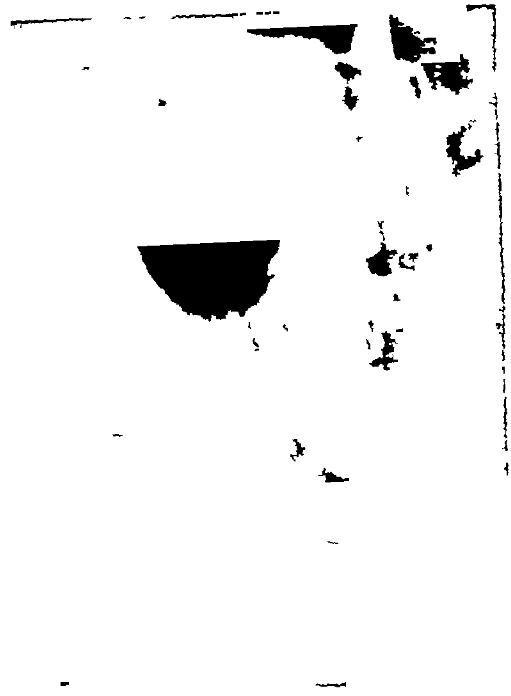


Fig 5

Fig 4 (Case 3) —Abscess of the posterior segment of the right upper lobe healed by instillation On May 23 1951 two years and one-half after the clinical healing bronchography still injects two small residual cavities

Fig 5 (Case 4) —Abscess of the apical segment of the right upper lobe treated by instillation in May 1950 Diodone bronchography on July 31 1950 huge residual cavity

II TREATMENT OF LUNG ABSCESS BY MEANS OF CATHETER INSTILLATIONS

Since 1945 we have used the catheter just described for therapeutic purposes This method proved most effective in the treatment of lung abscess The technique used was the same as the one described previously the same catheter and the same position that made a satisfactory opacification of the cavity possible at the time of the initial bronchography were used When the catheter was in the correct position the patient standing behind the fluoroscopic screen anesthesia completed by injecting 1 cc Pantocaine and the patient placed in such a position as to allow the injected fluid to remain as long as possible in the suppurative focus the therapeutic substance was then slowly injected

For a long while the antibiotic used was penicillin alone (one million units in [illegible] cc saline solution) Actually penicillin remains active in suppurations caused by anaerobes and often in those caused by gram plus bacteria. If a study of the organisms reveals a poor sensitivity to penicillin, sulfonamids shall be used (1 Gm.) or Aureomycin (0.10 Gm. plus sodium glycinate) or Chloromycetin (0.25 Gm.), but this latter is much more irritating for the bronchial tree. Thus we very often use a mixture of one million units of penicillin plus 0.10 Gm. Aureomycin plus 1 Gm. sulfadiazine for the same instillation.

Without neglecting the useful action of systemic antibiotics and of postural drainage, instillations are made every day or every other day. As a rule the patient becomes accustomed to them easily, as soon as the second or third instillation we have performed them without any preanesthesia. The patient's temperature very frequently shows a slight rise in the evening of the day when the instillation is made, but this is not alarming.

When the instillations prove effective, they do so promptly and their action can be felt in the decline of temperature and less abundant sputum. The total number of instillations can vary between six and about twenty, however, they should be discontinued if a marked improvement has not appeared after six or eight instillations. Most of our hospitalized patients have been submitted prior to their admission, to treatment by several systemic antibiotics or aerosols. Frequently, we have found that the very same antibiotic that has hitherto proved ineffective, becomes effective when injected right into the suppurating focus. It is quite likely that the sort of "chimney-sweeping" effected by the catheter as it penetrates into the draining bronchus has an importance of its own apart from the antibiotic action.

Since initial bronchography enables us to make sure that the substance is correctly injected into the abscess, we think our method as accurate and less dangerous than the transparietal injections favored by many authors.[15, 10, 22, 26] The use of a rubber catheter (placed with the patient behind the fluoroscopic screen) also seems to be preferable to the use of a bronchoscope,[17, 18, 28] since repeated bronchoscopies have a more traumatizing effect than instillations and because an injection performed through a bronchoscope, no matter how skillful the physician, is much less accurate than a catheter injection.

We have eliminated from our statistics all suppurations secondary to a pre-existing bronchopulmonary lesion: hydatid cyst, bronchial carcinoma, bronchiectasis, etc. We are concerned only with apparently primary abscess. We have also had to eliminate about fifteen cases in which our data were too incomplete and cases in which we lost contact with the patients. The remaining fifty-one cases between 1946 and 1952 form the basis of this study. All these patients were examined again in 1951 or 1952 by one of us and many have been submitted to tomographic and bronchographic checkups.

1. *Etiological Data.*—Of these patients 46 were men and 5 were women. Their ages appear in Table I.

TABLE I. AGES OF PATIENTS

AGE	20 or less	20 to 30	30 to 40	40 to 50	50 to 60	60 or over
No. of cases	2	1	8	20	14	4

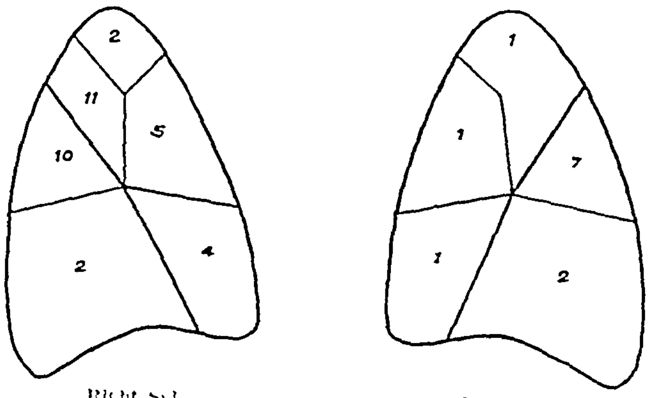
The age was not noted in two cases A definite etiology was apparent in seven of the fifty one cases only In one patient the abscess was subsequent to a sea bath with submersion in six patients it followed a surgical intervention (two gastrectomies one prostatectomy one cholecystectomy one drained appendicular abscess and one colon resection for a carcinoma) We have never come across an abscess subsequent to dental avulsion or tonsillectomy

2 *Topographic Data*—Table II shows the location of the suppurating foci we have treated

TABLE II LOCATION OF TREATED FOCI

RIGHT SIDE (40)			LEFT SIDE (15)		
Upper lobe 21	Apical s Anterior s Posterior s	2 5 11	Upper lobe 4	Apicodorsal Anterior	1 1
Middle lobe		4	Lingula		1
Lower lobe 12	Apical s Basal s	10 2	Lower lobe 10	Apical s Basal s	7 2

In fifty one patients we have found fifty-five suppurative foci a few patients presenting several foci Moreover we have placed in the corresponding lobe without accurately diagnosing the diseased segments some cases of extensive lobar suppuration Under these restrictions lung abscess appears in the great majority of cases as a segmental affection



Right Side Left Side

Fig 6 Location of the foci We give here only the location of strictly segmental foci

If we examine the disposition of these segmental foci such as they appear in Fig 6 we find that the affected segments are in order of frequency the posterior segment of the right upper lobe the apical segment of the right lower lobe the anterior segment of the right upper lobe (usually affected in its axillary branch) and the middle lobe As Matter pointed out the lung abscess is therefore to be most frequently found on each side of the interlobar fissure

3 *Results of the Treatment*—Table III sums up the therapeutic results

TABLE III. RESULTS OF CATHETER TREATMENT

I Cured			
A Clinically and anatomically completely healed	15	64%	72 5%
B Clinically healed (more than 2 years) Obvious anatomic sequelae	9		
C Clinically healed (more than 2 years) No bronchographic and tomographic checkup	9		
D Recent clinical recoveries (more than 3 months, less than 2 years)	4		
II Failure of medical treatment	14		27 5%

We have listed under *A* patients who have clinically recovered, in whom good tomographies and bronchographies show a complete *restitutio ad integrum* Case 5 is of this type

CASE 5—F O R, a 51 year old municipal clerk, was an alcoholic patient without any bronchial history He presented a subacute pneumonitis at the beginning of April, 1949 He was hospitalized on June 1, 1941 X ray films showed a voluminous opaque focus with a small light spot in the apical segment of the left lower lobe Four instillations of one million units of penicillin were given Lipiodol bronchograph revealed a bronchial short circuit caused by the cavity between the apical and a subapical bronchus sprung from the posterobasal bronchus, quite close to its origin (Fig 7) After four more instillations (Fig 8) the patient was radiologically and clinically healed Final bronchography on July 20, 1949, revealed a strictly normal apical segment The patient was examined again on Jan 27, 1951 He was in perfect clinical condition with a normal thoracic image

Group *B* consists of nine patients whose clinical recovery has remained excellent *at least for two years* after the end of the treatment, but in whom tomographies and especially bronchographies reveal anatomic sequelae—bronchiectasis or residual cavities at the site of the suppurative focus Such sequelae are very frequent if they are looked for under correct technical conditions but they do not necessarily imply an unfavorable prognosis Thus we have had under observation for several years some patients with residual cavities that have not become reinfected (we know how numerous are the cases of *bronchiogenic cysts which are located in a favorable draining position* in the upper lobe and so remain silent) and that have not caused any clinical disturbance in the patients Easily tolerated and susceptible to a slow spontaneous regression (Fig 4) such residual cavities do not in themselves require resection In the preceding section dealing with bronchography we have described two cases of this type (Cases 2 and 3)

We have grouped in a third category, *C*, nine patients who have been well for more than two years but *for whom no tomographic and bronchographic accurate anatomic checkups have been made* These patients have all been examined again in the course of 1951, they lead normal lives without any respiratory clinical manifestations, their standard radiologic film is normal or nearly so

The last group *D* includes patients whose clinical recovery has been complete for *at least three months* but whose treatment took place less than two years ago What lies in store for these patients who have been treated and who have "recovered" for a little time? For some who present important residual cavities the prognosis is guarded for others who present relatively unimportant anatomic sequelae we may hope that they will stay clinically healed and will not relapse Case 6 is an example

CASE 6.—A. U. D., an unskilled laborer, 31 years old, was without previous respiratory difficulty. On Nov. 7, 1950 he experienced hemoptysis followed by purulent expectoration. The patient was hospitalized on Nov. 17, 1950, and presented a large suppurative focus in the posterior segment of the right upper lobe. After a thirty-four day treatment of one million units of systemic penicillin and sulfathiazole there was an afebrile, radiologic improvement, yet pus was still raised. The patient was examined by us at the beginning of January, 1951. Bronchography on Feb. 5, 1951, revealed two persisting cavities in the

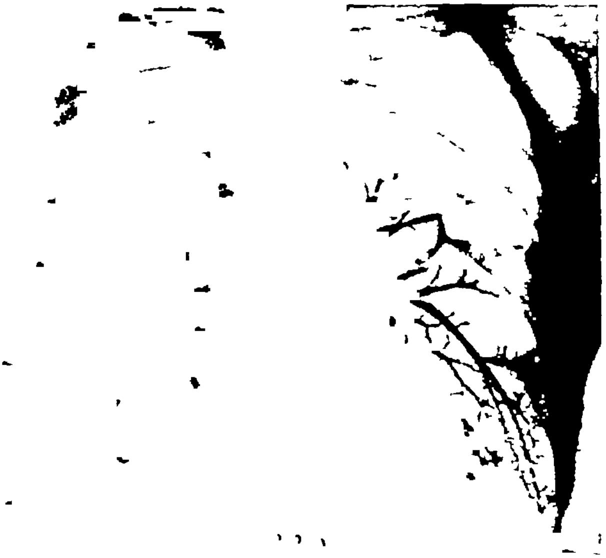


Fig. 7 (Case 5).—Abscess of the apical segment of the left lower lobe. Bronchography of the left lower lobe bronchial short circuit between the apical and a subapical bronchus.

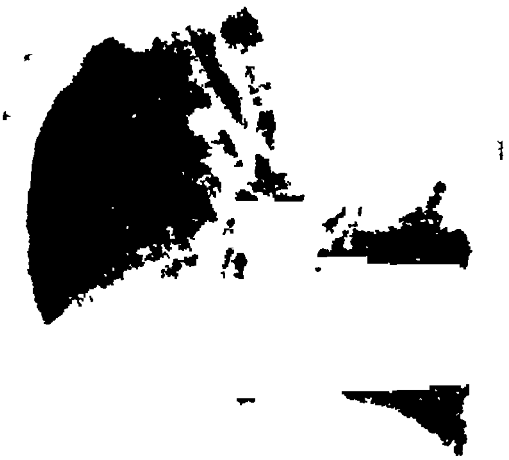


Fig. 8 (Case [illegible]).—The Metras sound in place for instillation.

posterior segment (Fig 9), icterus was observed After three months' rest, bronchography on May 7, 1951, indicated spontaneous regression of the residual cavities The patient was discharged, subject to occasional examinations Bronchography on Feb 11, 1953, showed small persisting cavities but a satisfactory clinical condition

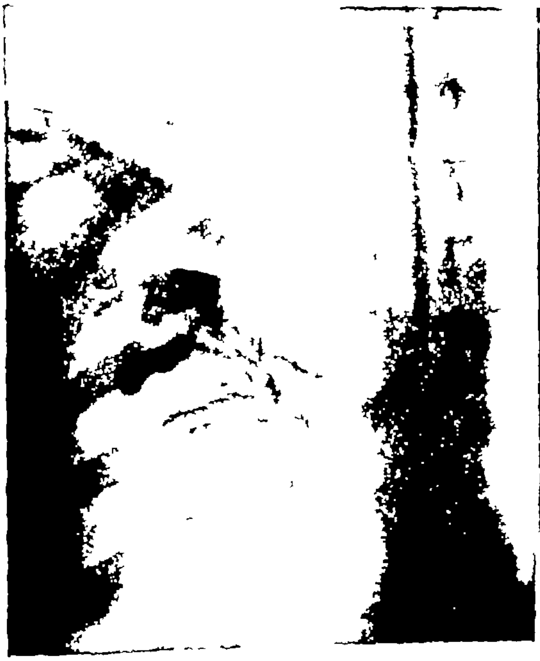


Fig 9

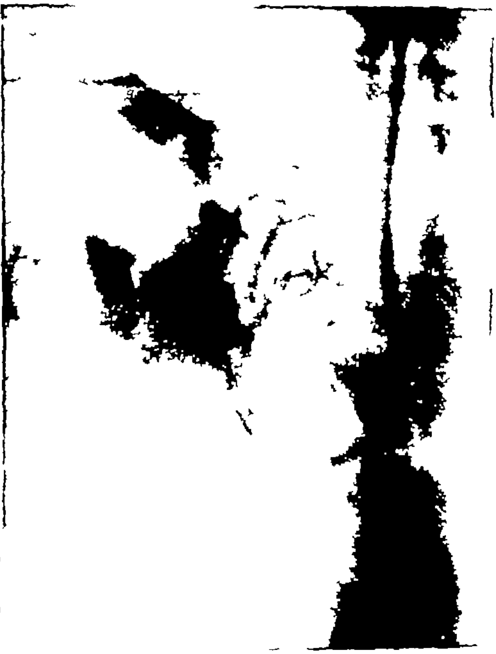


Fig 10

Fig 9 (Case 6) —Abscess in the posterior segment of the right upper lobe Clinical healing Diodone bronchography at the end of the treatment two residual cavities

Fig 10 —Abscess of the posterior segment of the upper lobe Initial Diodone bronchography

Here is a patient who improved under the instillations but who still presented two important residual cavities at the end of the treatment Should a segmental or a lobal resection be immediately performed? The evolution of these cavities showed that they had a marked tendency toward spontaneous regression The patient is still submitted to periodical checkups, but we hope that clinical recovery will last without relapse

In *Group II,* we have listed the fourteen cases in which the medical treatment failed It forms a rather heterogenous group composed of one patient who is still suffering from a chronic bronchorrhea that can certainly be related to the acute abscess, one patient who died of a brain abscess in spite of the radiologic clearing of the pulmonary lesions, one case in which the lung abscess was just one localization of the multiple suppurative foci of appendicular origin which proved eventually fatal, two cases of chronic suppuration in large residual cavities The nine remaining patients were submitted to resection either immediately after a previous cleaning up by means of instillations or following a relapse Three cases were right pneumonectomies, two right upper lobectomies two right lower lobectomies and two left pneumonectomies

Our statistics therefore show 64 per cent definitely healed, 72 5 per cent if we include those listed under *D* which date back to less than two years These figures may appear unimpressive, but three facts must be taken into consideration 1 We have adopted strict criteria of recovery What would be the results of mere medical treatment or of pneumotomy judged by the same standards? 2 A whole series of our patients came from a thoracic surgeon, on whom a group of doctors call for their worse cases 3 Last, we have included cases of chronic suppurations (which had gone on for more than three months when the treatment by instillations was begun), in such cases the percentage of medical recoveries hardly reaches 50 per cent, which brings our general statistics down

If we compare our statistics with the findings published by diverse authors we find that Mattei obtained 90 per cent recoveries in thirty-three cases of apparently primary acute abscesses Very encouraging findings were also published by J Berard,[7] H Benard,[5] Abel and his associates,[1] Bourgeois,[14] R Raynaud R Castaing,[19] Duroux, P Oudet,[61] J Terrasse,[65] M Fourestier and Le Boucher[3] R Petitjean[illegible] K P Bopp,[12] Mannes,[45] J A Pilheu,[68] M Zaccaria[illegible] and D Vega[illegible]

May these findings be considered as an improvement? Undoubtedly so in our opinion Indeed there have been lung abscesses *which healed spontaneously* It is not easy to establish in what percentage in view of the reduced field of many medical statistics and also in view of the fact that such spontaneous "healings" were often published without having gone through the test of time Archibald wrote that before disappearing one lung abscess was recorded in two or three statistics under the heading "healings" This humorous statement is certainly not entirely devoid of truth Mattei states in his book that out of 105 patients suffering from lung abscesses who were treated between 1935 and 1945 in his department by means of various methods only 17 or 15 per cent really recovered It does not appear that the percentage of genuine spontaneous healings could be higher than 30 or 40 per cent even in the best series of cases

The discovery of new antibiotics (Aureomycin terramycin bronchocillin) has undoubtedly increased the possibilities of general treatment but it also has increased the possibilities of local treatment and does not impair the principle of the superiority of local treatment in the case of a suppurative focus

5 *Indications for Surgery*—What we have just said of medical treatment and its failures defines the part we assign to surgery in the treatment of lung abscesses

When systemic and local antibiotic treatments have proved unable to dry up the suppuration entirely and when the clinical condition is satisfactory but a quite abnormal radiologic picture is still visible (as for instance when bronchography reveals dislocated bronchi a considerable or poorly drained residual cavity) the patient should undergo an operation

At this stage one type of intervention is advisable—resection All operative drainages of these residual foci would prove illusory we share J Mathey's opinion on this point On the other hand we do not think that a residual cavity if it is of small volume and in a good drainage position constitutes an itself an indication for resection We have seen that such cavities were often quite well tolerated and susceptible to spontaneous regression in the course of the years following clinical recovery If complications set in, such as hemoptysis and especially relapses in situ, we can then always resort to another cleaning up of the suppurative focus and then resection An imperfect anatomic healing should always be given a chance to undergo the test of time

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BRONCHOSPIROMETRY WITH THE CARLENS DOUBLE LUMEN CATHETER

EVALUATION AND EXERCISE TEST

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INTRODUCTION

ALTHOUGH it is well recognized that bronchospirometry is a necessary and valuable method for the study of respiratory physiology and for the determination of operative indication and the extent of operative involvement in ordinary chest surgery it is surprising that it is not popular This is probably due to its technical difficulties and also the general fear that it may cause not a little suffering to the patient Since Jacobaeus a number of reports on the bronchospirometric method have been published Many workers have tried to modify the technique in order to make the procedure less trying for the patient

We have performed bronchospirometry on about 200 tuberculous patients as a routine examination before thoracic operations during the two years from April, 1950 to April 1952 at National Okayama Sanatorium The bronchoscope which we used in this series was a flexible metal single lumen bronchoscope modified by Urabe and his associates[1] It was a Norris-type catheter, equipped with mouthpiece and nose clip instead of the face mask

As we gained added experience the following disadvantages of this catheter were noticed 1 There were often difficulties in introducing the catheter into the left main bronchus because of the friction caused by the external rubber coat this was especially true among women patients 2 A tear often occurred in this rubber coat during introduction 3 Aspiration of secretions was difficult 4 In one patient whose right lung function was moderately impaired the value recorded is much less as was actually estimated 5 The use of a mouthpiece and nose clip makes the patients feel suffocated and causes labored breathing

As a result successful recordings were obtained only in about one quarter of the total number of persons examined

In 1949 Carlens described a new type of a double lumen catheter and reported good results In June 1952 we received this catheter at the present

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time it has been used in almost 100 cases and has been found to fulfill all the requirements of such an instrument. Because we have actually recognized its superiority to ordinary old bronchospirometry and since very little literature has been available since Carlens' original article, I think it is important to report our experiences with this catheter.

TECHNICAL PROCEDURE

The premedication and topical anesthesia are approximately the same as those employed for bronchoscopy. Half an hour before the procedure, a hypodermic injection of 60 to 100 mg. of morphine hydrochloride and 0.5 mg. of atropine sulfate is administered. Anesthesia of the throat and larynx is secured by the spraying of 5 per cent cocaine hydrochloride, the trachea and main bronchus are then anesthetized by fractional instillation of about 2 ml. of the same solution. We use a Gebauer-type twinspirometer with the tanks containing pure oxygen. In most cases the catheter is very easily introduced under mirror guidance, even without the use of stylet and without tying the rubber hook as Carlens describes. We have not as yet encountered an instance in which introduction of the catheter was impossible. In this regard the catheter is much superior to an ordinary old bronchoscope. It is very easy to feel when the catheter is introduced into the correct position. Carlens states, "It is provided with a little hook that is *automatically* engaged by the carina." It is really like that. When it is once introduced into the correct position and fixed by the inflation of two cuffs, it scarcely slips by a moderate movement of the body or changing of its position. Therefore examinations such as exercise test and those made in different positions are easily carried out.

In most cases the test was smoothly performed for forty minutes without any discomfort to the patient. After examination the patient always stated that he had experienced less pain than by bronchoscopy, also the medical students, on whom the tests to be described were made, said they were able to breathe more easily than in ordinary external spirometry.

There is no doubt that the catheter has the following features of superiority. 1. It requires no skilled technique and no complex equipment. 2. Introducing the catheter is easy, and it can be easily placed in the correct position. 3. The tests made during exercise and in different positions can easily be carried out. 4. It is much less trying for patients than the ordinary old bronchoscope. 5. Sputum can be easily aspirated.

COMPARISON OF CARLENS TUBE AND FLEXIBLE SINGLE LUMEN METAL BRONCHOSCOPE

It is well known that in bronchospirometry there is an increase in respiratory frequency and minute ventilatory volume, and a consequent increase in oxygen consumption, with the corresponding decrease in vital capacity and maximum breathing capacity. This is brought about by the strain and apprehension of the patient at the examination, the effects of the local anesthetic and the modification of the breathing mechanism which causes the patient to breathe through a stenosis. Urabe[1] reported an average increase of 35.6 per cent in minute volume and 29.7 per cent increase in

TABLE I COMPARISON OF SUMMATION OF OXYGEN CONSUMPTION AND VITAL CAPACITY FROM BOTH LUNGS BY FLEXIBLE SINGLE LUMEN METAL BRONCHOSCOPE AND BY ORDINARY SPIROMETRY IN 10 TUBERCULOUS PATIENTS

CASE	OXYGEN CONSUMPTION (C.C)				VITAL CAPACITY (C C)			
	RIGHT	LEFT	SUM	R + L / S (%)	RIGHT	LEFT	SUM	R + L / S (%)
1	160	200	308	116 8	1040	1830	3030	94 7
2	230	100	220	150 0	1350	870	2300	96 5
3	80	230	250	124 0	460	1120	1770	89 2
4	330	40	300	123 3	2000	230	2250	99 1
5	300	150	276	163 0	900	580	1550	94 8
6	360	130	350	140 0	2250	1320	3620	98 5
7	300	77 3	225	165 8	880	300	1390	84 8
8	45	220	157	162 4	1440	120	1420	107 6
9	255	180	350	124 2	1640	1070	2900	93 4
10	220	100	330	96 9	660	1420	2000	104 0
Average				133 6				92 1

S—Vital capacity obtained by ordinary spirometry

oxygen consumption and an average decrease of 9 2 per cent in vital capacity and of 21 9 per cent in maximum breathing capacity in ten healthy male adults when a flexible single lumen metal bronchoscope was used Suzuki[3] found an average increase of 32 per cent in oxygen consumption and an average decrease of 20 0 per cent in vital capacity in sixteen healthy adults using the double lumen metal brochoscope which he designed In our series, increase in oxygen consumption and decrease in vital capacity were 33 6 per cent and 7 9 per cent on the average respectively, in the ten tuberculous patients examined with the flexible single lumen metal bronchoscope (Table I) If we take the increase in oxygen consumption as an index of strain on the patient and the decrease in vital capacity as an index of stenosis breathing and compare the Carlens tube with the old bronchoscope in regard to these two points it is self evident that the former is more physiologic than the latter

As Table II shows, in the test on the healthy medical students the increase in oxygen consumption and the decrease in vital capacity average 9 3 per cent and 0 7 per cent, respectively As Table III shows, in the test made on

TABLE II COMPARISON OF SUMMATION OF OXYGEN CONSUMPTION AND VITAL CAPACITY FROM BOTH LUNGS BY CARLENS TUBE AND BY ORDINARY SPIROMETRY IN 10 STUDENTS

CASE	OXYGEN CONSUMPTION (C C)				VITAL CAPACITY (C C)			
	RIGHT	LEFT	SUM	R + L / S (%)	RIGHT	LEFT	SUM	R + L / S (%)
1	165	150	320	98	1910	1710	3650	99 1
2	180	180	310	116	2010	1740	3800	98 7
3	155	155	285	109	2170	2100	4250	100 4
4	187	95	255	110	1610	1490	2940	105 4
5	113	156	260	103	2040	1760	3480	109 0
6	165	205	330	112	1590	1540	3780	82 8
7	190	185	345	108	1530	1490	3050	99 0
8	201	185	315	123	1950	1840	3960	96 0
9	117	105	[illegible]	84	1830	2010	3760	102 1
10	211	167	[illegible]	108	2100	2070	4080	102 7
Average	[illegible]	[illegible]	[illegible]	109 [illegible]	1880	1770	3675	99 [illegible]
[illegible]			[illegible]				[illegible]	

S—Vital capacity obtained by ordinary spirometry

TABLE III COMPARISON OF SUMMATION OF OXYGEN CONSUMPTION AND VITAL CAPACITY FROM BOTH LUNGS BY CARLENS TUBE AND BY ORDINARY SPIROMETRY IN 10 TUBERCULOUS PATIENTS

CASE	OXYGEN CONSUMPTION (C.C.)				VITAL CAPACITY (C.C.)			
	RIGHT	LEFT	SUM	$\frac{R+L}{S}$ (%)	RIGHT	LEFT	SUM	$\frac{R+L}{S}$ (%)
1	110	220	265	124.5	570	820	1420	97.8
2	200	103	205	147.8	820	530	1440	90.0
3	210	90	280	103.5	1070	460	2080	73.5
4	35	160	140	139.2	140	1160	1370	94.8
5	105	155	205	126.8	510	690	1290	93.0
6	100	200	308	97.4	920	930	1920	96.3
7	230	55	245	116.3	280	1540	2050	88.7
8	185	90	265	103.7	1660	650	2190	105.4
9	120	215	318	105.3	680	960	1430	114.6
10	60	180	255	94.1	310	1030	1350	99.2
Average				113.7				94.8

S—Vital capacity obtained by ordinary spirometry

tuberculous patients these figures are 13.7 per cent and 5.2 per cent, respectively. This demonstrates that the test with Carlens tube can be carried out on the diseased as well as on the healthy person. From this fact the superiority of the Carlens tube is well understood. The difference in the increase of oxygen consumption during bronchospirometry is marked, revealing that this procedure is much less trying for the patient than any older method.

BRONCHOSPIROMETRY DURING EXERCISE

Although bronchospirometry is a more advanced method than the usual spirometry as a test of lung function, it shows only a static value as in the case of the latter. It is not only useful for the study of important physiologic questions, but it is also necessary in practical medicine to be informed of the dynamic function of each lung and the adaptability of each lung to physical strain.

Following Carlens' example[4] we have constructed a cycleergometer, on which the subject is able to pedal in the supine position. The test is made in the following manner. During the first five minutes an ordinary bronchospirometry is carried out in the supine position. Then the patient continuously pedals the ergometer at the speed of sixty rotations a minute for three minutes in connection with the spirometer, at the same time a tracing is recorded. Exercise tests have been made in this manner on fifteen tuberculous patients. Principally, the oxygen intake was calculated from the tracing at rest and during exercise and the figures for the oxygen intake for each lung during exercise were presented in percentage of the corresponding figures at rest.

As Table IV shows, the increase of oxygen intake during exercise test in the worse lung varies between 240 per cent and 493 per cent, averaging 350.9 per cent. In the better lung the result was 197 per cent 455 per cent and 351.6 per cent respectively, in comparison with the basal values. This means that the average increase rate of oxygen consumption during exercise is equal in both the worse and the better lung. It was expected that the lung which was inferior to the other because of tuberculous involvement and because of its affected function as demonstrated by bronchospirometry at rest would show

Table IV Comparison of Differential Oxygen Consumption for Each Lung at Rest and During Exercise (c c)

CASE	AT REST				DURING EXERCISE			
	RIGHT	LEFT	R	L	RIGHT (%)	LEFT (%)	R	L
1	107	210	34	66	300 (280)	613 (292)	33	67
2	25	257	9	91	60 (240)	840 (326)	7	93
3	115	345	25	75	510 (443)	850 (247)	37	63
4	210	82	72	28	500 (238)	200 (244)	71	29
5	105	173	38	62	320 (304)	630 (364)	34	66
6	170	190	47	53	468 (292)	572 (301)	45	55
7	180	210	46	54	590 (327)	675 (321)	47	53
8	147	167	47	53	320 (217)	330 (197)	49	51
9	198	110	64	36	693 (350)	360 (372)	66	34
10	173	130	57	43	710 (408)	500 (384)	59	41
11	215	98	69	31	660 (307)	280 (285)	70	30
12	160	180	47	53	448 (280)	540 (300)	45	55
13	170	180	42	58	640 (493)	820 (455)	44	56
14	160	100	62	38	590 (380)	380 (370)	61	39
15	233	105	69	31	870 (373)	470 (438)	65	35
Average	155	170	47.7	52.3	512 (330)	537 (316)	48.8	51.2

The numbers in parentheses indicate the rate of increase of oxygen consumption in percentage

relatively smaller increases in the oxygen consumption during exercise than the healthier lung but that was not the case We were surprised to find that the part played by each lung did not change beyond the limits of the error of the method during work as compared with the rest values (Case 2 in Table IV is a good example)

Therefore as Carlens pointed out the theory that the function of the inferior lung approaches its maximum limit of capacity with regard to oxygen intake closer, even during rest than the healthy lung cannot be correct But the ventilatory equivalent of the superior lung shows a tendency to slightly more favorable values during exercise as compared with that of the inferior lung (Table V) The inhalation of pure oxygen being of course not physiologic more detailed research is necessary Two cases are illustrated (Figs 1 and 2)

Table V Comparison of Ventilation Equivalent for Each Lung at Rest and During Exercise

CASE	AT REST		DURING EXERCISE	
	RIGHT	LEFT	RIGHT	LEFT
1	[illegible]	1.9	3.6	1.8
2	[illegible]	[illegible]	[illegible]	0.91
3	[illegible]	2.1	1.4	1.5
4	[illegible]	4.6	1.4	2.2
5	[illegible]	[illegible]	2.2	[illegible]
6	[illegible]	4.2	1.9	1.8
7	[illegible]	2.0	1.7	1.2
8	[illegible]	1.8	1.8	[illegible]
9	3.1	4.5	1.1	1.6
10	[illegible]	[illegible]	1.2	1.2
11	[illegible]	1.9	1.2	1.8
12	[illegible]	[illegible]	1.8	1.2
13	[illegible]	[illegible]	1.1	0.93
14	[illegible]	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	1.1	[illegible]

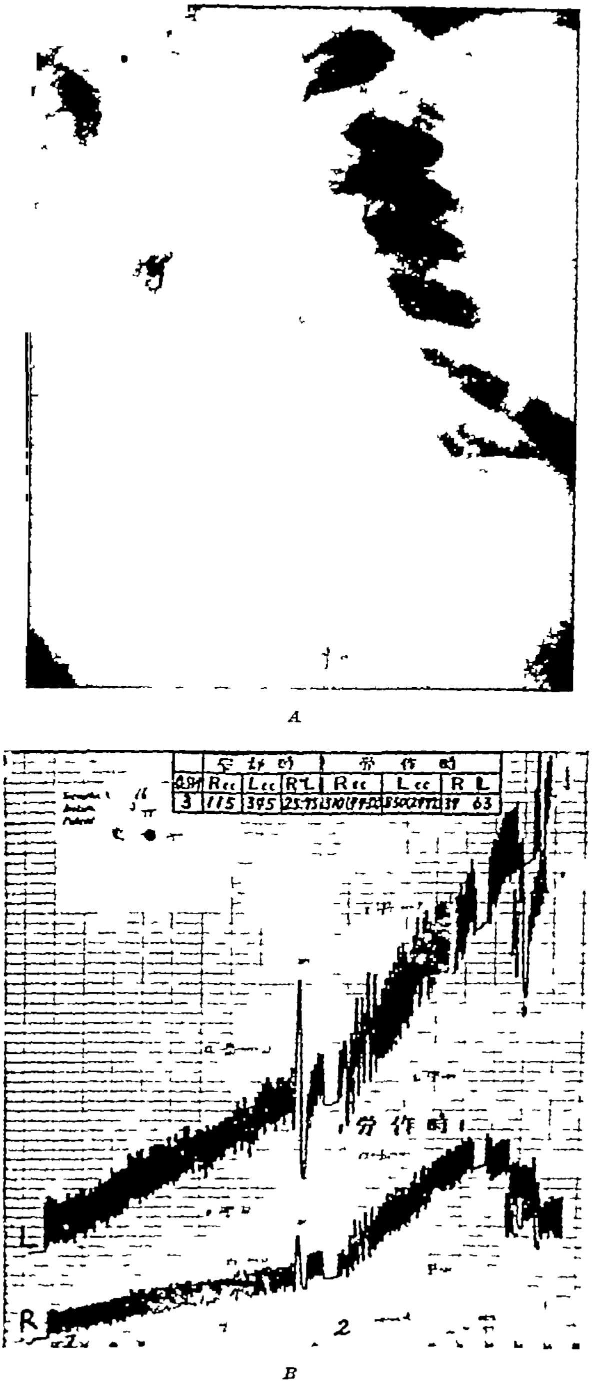
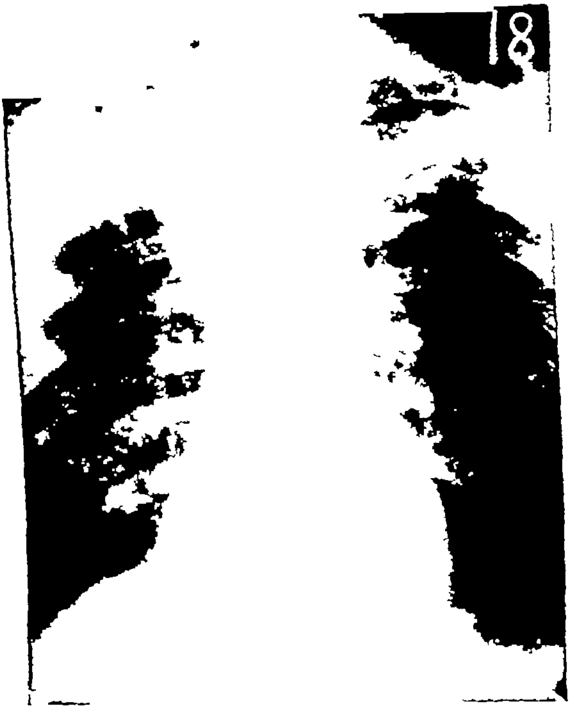
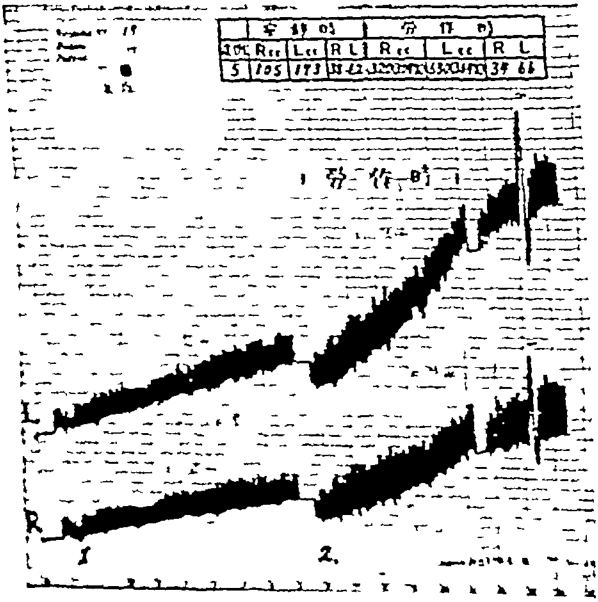


Fig 1 (Case 3) — A Roentgenogram of the chest Right sided postthoracoplasty tuberculosis with moderately thickened pleura. B Bronchospirometric tracing R right lung L left lung 1 bronchospirometry at rest 2 during exercise



A



B

[illegible] Light [illegible] tuberculosis with [illegible] tracing *1* right lung *2* left lung [illegible] during [illegible]

SUMMARY AND CONCLUSION

1 Experiences with the Carlens double lumen catheter have been described and its superiority emphasized

2 Using this catheter it was found that the increase in oxygen consumption during bronchospirometry in ten healthy medical students was on the average 9 3 per cent and the decrease in vital capacity was 0 7 per cent

3 These figures were 11 3 per cent and 5 2 per cent, respectively, in ten patients with pulmonary tuberculosis

4 It was noted that these same figures were 33 6 per cent and 7 2 per cent, respectively, on bronchospirometry with a modified Norris-type flexible single lumen metal bronchoscope

5 A new lung function test (bronchospirometry during exercise) and results obtained with fifteen tuberculous patients were described We agree with Carlens in the following conclusions (a) The theory that the function of the diseased lung with regard to oxygen intake approaches, even at rest, more closely the maximum limit of its capacity is not correct (b) It was found that the part played by each lung did not change beyond the limits of the error of the method during work as compared with the rest values

BRONCHOSPIROMETRY IN DIFFERENT POSITIONS

Studies of the change of lung function in different positions are found in the literature, but they have been made for the most part by a spirometric method Regarding bronchospirometric study, few articles are available in the literature at present This is mainly due to technical difficulties Carlens tube has settled these difficulties

It is important both for physiologic study and for practical medicine to be informed of the effect of postural changes on the lung function We have studied this problem on ten healthy medical students by bronchospirometry with the Carlens tube in supine sitting, and both lateral positions

TECHNICAL PROCEDURE

Premedication and topical anesthesia was similar to that previously described The test was done in the following manner First an ordinary

TABLE VI DIFFERENTIAL TIDAL AIR (C C /MIN) AND PER CENT OF TOTAL

CASE	SUPINE				RIGHT LATERAL				LEFT LATERAL				SITTING			
	VOLUME		%		VOLUME		%		VOLUME		%		VOLUME		%	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
1	250	240	51	49	260	210	55	45	200	220	48	52	240	230	51	49
2	380	240	61	39	440	260	63	37	190	360	35	65				
3	360	290	55	45	330	220	60	40	240	260	48	52	400	410	49	51
4	210	200	51	49	200	180	54	46	180	190	48	52	230	220	51	49
5	310	260	54	46	300	280	52	48	280	310	47	53	310	310	50	50
6	540	530	51	49	530	530	50	50	580	570	51	49				
7	300	290	51	49	340	280	55	45	310	320	49	51	410	350	54	46
8	420	410	51	49	400	370	52	48	330	400	45	55	550	510	52	48
9	640	620	51	49	680	630	52	48	680	710	48	52	700	620	53	47
10	580	570	51	49	610	530	54	46	520	570	47	53				
Average	399	365	52	48	409	349	54	46	351	391	47	53	408	380	52	48

bronchospirometry was performed in the supine position for ten minutes, then subsequently in the right lateral and in the left lateral positions for five minutes, respectively, and last the tracing was recorded in the sitting position for ten minutes The following values can be calculated for each lung from each tracing tidal air, reserve air, vital capacity, minute ventilation volume, minute oxygen intake and ventilation equivalent

RESULTS OBTAINED

1 *Tidal Air (Table VI)* —As Table VI shows, in all but one person the tidal air of the right lung was greater than that of the left lung in the supine position It was true in the right lateral position in all instances But in the left lateral position except in one student tidal air of the left lung was greater than that of the right lung and it increased in five cases and decreased in five cases with an average increase of 26 c c as compared with that found in the supine position It is noted that in the lateral position the tidal air of the under lung was greater than that of the upper lung and showed a slight increase in absolute amount The tidal air of the right lung increased in five cases and decreased in five cases with an average increase of 10 c c in the right lateral position as compared with the supine No definite change was found in the sitting position These differences are not statistically significant ($P > 0.01$)

TABLE VII DIFFERENTIAL RESERVE AIR (C C) AND PER CENT OF TOTAL

	SUPINE				RIGHT LATERAL				LEFT LATERAL				SITTING			
	VOLUME		%		VOLUME		%		VOLUME		%		VOLUME		%	
CASE	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
1	450	410	52	48	370	490	40	60	650	420	60	40	520	480	52	48
2	400	370	52	48	410	470	47	53	920	350	72	28				
3	660	580	53	47	490	720	40	60	870	550	61	39	970	820	54	46
4	440	440	50	50	430	720	37	63	820	390	68	32	700	580	55	45
5	520	480	52	48	500	690	42	58	780	380	67	33	740	720	51	49
6	510	510	50	50	400	340	54	46	500	420	54	46				
7	480	470	51	49	440	570	43	57	670	540	55	45	590	560	51	49
8	510	480	51	49	460	1000	32	68	950	400	70	30	970	950	51	49
9	800	770	52	48	660	810	45	55	910	450	67	33	970	820	54	46
10	760	730	51	49	560	790	42	58	760	460	62	38				
Average	[illegible]	528	52	48	468	660	41	59	787	437	64	36	780	704	52	48

2 *Reserve Air (Table VII)* —Reserve air of the right lung was greater than that of the left lung in eight persons while in a supine position In the right lateral position reserve air of the right lung moderately decreased in all instances while on the other hand reserve air of the left lung moderately increased It is reversed in the left lateral position That is in the lateral position reserve air of the under lung moderately decreased and that of the upper lung correspondingly increased as compared with the supine This difference is statistically significant ($P < 0.01$) A moderate increase of reserve air was noted in both lungs when the student was in the sitting position

TABLE VIII. TOTAL VITAL CAPACITY (C C)

CASE	SUPINE	RIGHT LATERAL (%)	LEFT LATERAL (%)	SITTING (%)
1	3080	2220 (72 0)	3000 (97 4)	3120 (100 1)
2	3750	3350 (89 3)	3440 (91 6)	
3	4270	4400 (103 0)	3970 (92 8)	4420 (103 2)
4	3650	3610 (99 0)	3580 (98 1)	3640 (99 5)
5	3800	3790 (99 5)	3780 (99 6)	3930 (103 5)
6	3130	2620 (83 6)	2930 (93 5)	
7	3020	3150 (105 0)	3170 (105 0)	3520 (116 5)
8	3790	3920 (103 3)	3790 (100 0)	4190 (110 0)
9	3740	2930 (78 5)	3590 (96 6)	3740 (100 0)
10	4190	3740 (89 2)	3630 (88 8)	
Average	3642	3370 (93 0)	3488 (96 0)	3794 (105 0)

The numbers in parentheses indicate the percentage as compared with the supine figures

3 *Vital Capacity (Tables VIII and IX)*—In the right lateral position the total vital capacity of both lungs increased in three cases and decreased in seven cases, with an average decrease of 269 c c , or 7 4 per cent In the left lateral position an increase in one instance, a decrease in 8, and no change in another were noted, with an average decrease of 154 c c , or 4 3 per cent That is, in the lateral position the total vital capacity slightly decreased as compared with the supine But this difference was not statistically significant (P > 0 01) In the sitting position it increased in five cases and on the average an increase of 173 c c , or 5 per cent, was observed

Differential Vital Capacity—In the supine position, vital capacity of the right lung was greater than in the left lung in all cases and the ratio between both lungs was 52 48 In the right lateral position vital capacity of the right lung was greater than that of the left lung in six cases, but smaller in four cases, and the ratio changed to 51 49 In the left lateral position in eight cases vital capacity of the right lung was greater than that of the left lung and the ratio changed to 51 49 A slight increase was seen in the sitting position But this difference was not statistically significant (P > 0 01) In various positions except the left lateral position vital capacity of the right lung is greater than that of the left lung, but the total vital capacity shows inconstant change

TABLE IX. DIFFERENTIAL VITAL CAPACITY (C C) AND PER CENT OF TOTAL

CASE	SUPINE				RIGHT LATERAL				LEFT LATERAL				SITTING			
	VOLUME		%		VOLUME		%		VOLUME		%		VOLUME		%	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
1	1600	1480	52	48	1080	1140	48	52	1580	1420	53	47	1620	1500	52	48
2	2010	1740	54	46	1930	1420	58	42	1900	1540	55	45				
3	2170	2100	51	49	2170	2230	49	51	2050	1920	52	48	2300	2120	52	48
4	1930	1720	53	47	1830	1780	51	49	1880	1700	52	48	1900	1740	52	48
5	2040	1760	54	46	1960	1830	52	48	2100	1680	56	44	1980	1950	50	50
6	1590	1540	51	49	1430	1190	55	45	1500	1430	51	49				
7	1530	1490	51	49	1620	1530	52	48	1480	1690	47	53	1820	1700	52	48
8	1950	1840	52	48	2000	1920	51	49	1950	1840	52	48	2220	1970	52	48
9	1980	1760	53	47	1520	1410	52	48	1850	1740	52	48	2020	1720	54	46
10	2160	2030	52	48	1820	1920	49	51	1560	2070	43	57				
Average	1896	1746	52	48	1736	1637	51	49	1785	1703	51	49	1980	1814	52	48

TABLE X. DIFFERENTIAL MINUTE VOLUME IN LITERS AND PER CENT OF TOTAL

	SUPINE				RIGHT LATERAL				LEFT LATERAL				SITTING			
	VOLUME		%		VOLUME		%		VOLUME		%		VOLUME		%	
CASE	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
1	4.8	4.6	52	48	5.3	4.3	55	45	4.9	4.7	51	49	5.3	5.1	51	49
2	4.6	2.9	61	39	4.4	2.6	63	37	2.7	5.0	35	65				
3	4.7	3.7	56	44	4.6	3.0	61	39	3.1	3.4	48	52	4.8	4.9	49	51
4	4.3	4.1	51	49	4.4	4.0	52	48	3.8	4.0	49	51	4.6	4.4	51	49
5	4.9	3.6	58	42	4.2	3.9	52	48	3.9	4.3	48	52	4.3	4.3	50	50
6	7.5	7.4	50	50	7.4	7.4	50	50	7.5	7.4	50	50				
7	4.2	4.0	51	49	4.9	4.0	55	45	4.7	4.8	49	51	5.8	4.8	55	45
8	6.3	6.1	51	49	6.8	6.3	52	48	5.3	6.4	45	55	8.2	7.6	52	48
9	11.5	11.1	51	49	12.0	11.1	52	48	11.5	12.0	49	51	12.6	11.2	53	47
10	10.4	10.3	50	50	11.9	10.3	54	46	9.6	12.[illegible]	46	54				
Average	6.3	5.8	52	48	6.7	5.8	54	46	5.7	6.4	47	53	6.5	6.0	52	48

TABLE XI. TOTAL OXYGEN CONSUMPTION (C.C./MIN.)

CASE	SUPINE	RIGHT LATERAL (%)	LEFT LATERAL (%)	SITTING (%)
1	228	233 (102)	218 (95)	302 (134)
2	360	357 (99)	358 (99)	
3	310	334 (108)	370 (119)	400 (129)
4	340	290 (85)	300 (88)	325 (99)
5	269	275 (104)	268 (100)	288 (107)
6	345	325 (94)	350 (101)	
7	375	382 (102)	325 (87)	382 (102)
8	390	387 (99)	360 (92)	380 (97)
9	440	473 (107)	410 (93)	440 (100)
10	473	459 (95)	430 (91)	
Average	353	352 (100)	338 (96)	360 (107)

The numbers in parentheses indicate the percentage of intake compared with the supine position intake.

TABLE XII. DIFFERENTIAL OXYGEN ABSORPTION IN CUBIC CENTIMETERS AND PER CENT OF TOTAL

	SUPINE				RIGHT LATERAL				LEFT LATERAL				SITTING			
	VOLUME		%		VOLUME		%		VOLUME		%		VOLUME		%	
CASE	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
1	120	108	53	47	133	100	57	43	108	110	50	50	160	142	53	47
2	180	180	50	50	247	110	69	31	165	193	46	54				
3	155	155	50	50	187	147	56	44	170	200	46	54	220	180	55	45
4	170	170	50	50	160	130	55	45	125	175	42	58	180	145	55	45
5	113	156	42	58	150	125	55	45	98	170	37	63	125	163	43	57
6	175	170	51	49	245	80	75	25	160	190	46	54				
7	193	187	51	49	203	180	53	47	135	190	45	55	195	187	51	49
8	205	185	53	47	220	167	57	43	185	175	51	49	205	175	54	46
9	230	210	52	48	313	160	66	34	140	270	34	66	240	200	55	45
10	240	237	51	49	273	186	60	40	150	280	35	65				
Average	178	175	50	50	217	139	61	39	146	195	43	57	189	170	52	48

4. *Minute Ventilation (Table X).*—As Table X shows, a similar tendency is noted as in tidal air.

5. *Minute Oxygen Intake (Tables XI and XII).*—The total oxygen intake of both lungs increased in five students and decreased in five in the right lateral position. But these changes were slight and there was no change in the average. In the left lateral position, intake decreased in eight cases and increased in two cases, with an average decrease of 14 c.c. or 4 per

cent. In the sitting position the average increase of 172 c.c., or 5 per cent, was noted.

Differential Oxygen Consumption.—Minute oxygen intake of the right lung was greater than that of the left lung in six students, equal in three, and smaller in one in the supine position. In the right lateral position minute oxygen intake of the right lung (the under lung) was greater than that observed in the supine in all cases but one (Case 4). On the other hand in Case 4, oxygen intake of the left lung showed a further decrease than while in the supine position. It was noted that in the left lateral position oxygen intake of the left lung was greater than the intake of the right lung in all but Case 8. In Case 8 the oxygen intake of the right lung showed a corresponding decrease as compared with the intake in the supine position. It was noted, therefore, that the under lung in the lateral position showed a definite increase in the amount and percentage of the total oxygen consumed as compared with the supine position, and it was reversed in the upper lung. This difference was statistically significant ($P < 0.01$). The right lung in the right lateral position showed a slight but definite increase over the left lateral position.

6. *Ventilation Equivalent (Table XIII).*—The ventilation equivalent of the under lung in the lateral position decreased, and on the other hand it increased in the upper lung over the supine valve. In the right lateral position the right lung showed an average decrease of ventilation equivalent from 3.5 to 3.2, the left lung showed an average increase from 3.2 to 4.7 as compared with the supine position. In the left lateral position the right lung demonstrated a slight increase, and the left lung showed no change. This was due to increased oxygen absorption with relatively less increase in the total air breathed by the under lung. Changes in the ventilation equivalent were considered merely reflections of the change in oxygen absorption and minute ventilation as Rothstein stated.

TABLE XIII. VENTILATION EQUIVALENT

CASE	SUPINE		RIGHT LATERAL		LEFT LATERAL		SITTING	
	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT
1	3.9	4.1	4.0	4.3	4.5	4.3	3.3	3.6
2	2.5	1.6	1.8	2.3	1.6	2.6		
3	3.0	2.3	2.4	2.0	1.8	1.7	2.1	2.7
4	2.7	2.6	2.7	3.1	3.0	2.3	2.5	3.0
5	3.8	2.3	2.8	3.1	4.0	2.5	3.4	2.6
6	4.2	4.3	3.0	9.2	4.7	3.9		
7	2.2	2.1	2.4	2.2	3.0	2.5	2.9	2.6
8	3.0	3.3	3.1	3.7	2.8	3.6	4.0	4.3
9	5.0	5.3	4.1	7.5	8.2	4.4	5.2	5.6
10	4.3	4.4	4.3	5.5	3.4	4.3		
Average	3.5	3.2	3.1	4.3	3.7	3.2	3.3	3.5

DISCUSSION

Among results described two outstanding changes regarding reserve air and minute oxygen intake will be noted. It is well known that the factors that affect the function of lungs are three: conditions of the pleural cavity, the diaphragm, *and parenchymal lesions*.

Lowys[6] reported that in the lateral position the diaphragm increases its movement, and Fischer[7] stated that in the lateral position the diaphragm of the under side elevates, that of the upper side descends and the heart and mediastinum shift to the under side

Akutsu[8] revealed radiologically that in normal persons in the lateral position the diaphragm of the under lung elevates and also increases its movement, the movement of the upper thoracic cage decreases at the same time He further stated that movement of the diaphragm of the under side is moderately greater than that of the upper side Rothstein[5] studied bronchospirometry in the recumbent position and found that in the lateral position oxygen intake of the under lung increases, he attributed this increase to an increase of blood flow through the under lung caused by gravitation In our series the under lung in the lateral position showed a slight increase of tidal air and of minute ventilation a slight decrease of vital capacity and a definite decrease of reserve air This change can probably be attributed to the effect of the movement of the diaphragm It is apparent that tidal air and minute ventilation increase in the under lung in the lateral position In addition to this if the blood flow through the under lung is greater it is natural that the oxygen intake of the under lung increases However it is not known which is more effective ventilatory or cardiovascular changes further research is necessary There is no doubt that the sitting position is less resistant to respiration than other positions

SUMMARY AND CONCLUSION

1 Bronchospirometry in the supine and both lateral positions has been performed on ten normal persons Seven of them also had determinations made while sitting

2 A slight increase in the absolute amount and a definite increase in the percentage of tidal air was noted in the under lung in the lateral position

3 A definite decrease both in the absolute amount and in the percentage of reserve air was noted in the under lung in the lateral position

4 Total vital capacity decreased by an average of 7 per cent while lying on the right side and 4 per cent while lying on the left Differential vital capacity of both under and upper lungs showed a slight decrease as compared with that found while supine

5 A slight but definite increase both in the absolute amount and percentage of minute ventilation was noted in the under lung in the lateral position

6 The total oxygen consumption showed no change in the right lateral position and an average decrease of 4 per cent in the left lateral position as compared with while supine But a definite increase both in the absolute amount and in the percentage of oxygen consumption was noted in the under lung in the lateral position

7 The ventilation equivalent decreased in the under lung indicating increased efficiency

8 A definite increase of oxygen consumption in the under lung in the lateral position is attributable to the increase in minute ventilation and in blood flow through the same lung

9 In the sitting position tidal air, reserve air, vital capacity, minute ventilation, and total oxygen consumption all increased on the average by 3 1, 36, 5 3 3 and 7 per cent, respectively The sitting position was considered less resistant for respiration than other positions

I wish to express my hearty thanks to Professor S Tsuda for his guidance

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A NEW CATHETER FOR BRONCHOSPIROMETRY WHICH COMBINES THE ADVANTAGES OF THE DOUBLE LUMEN AND SINGLE LUMEN CATHETERS

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MILANO, ITALY

All the double lumen catheters used for bronchospirometry have the disadvantage of being too obstructive, although this is true in a lesser degree for the Carlens tube.[1] This causes unsatisfactory procedures in many cases. Attempts have been made to substitute single lumen catheters for the double lumen catheters[2, 3] in order that less space may be occupied by the solid structures of the instrument. A strong objection to the single lumen catheter is the variable degree of free space left to the air flow of the right side by the vocal cords; in some instances all passage may be obstructed completely or almost completely.

I have designed a new catheter for bronchospirometry which combines the advantages of the double lumen with the single lumen catheter. It consists of a tube 43 cm. in length destined for the left main bronchus. It bears at the distal end an inflatable rubber cuff. Its diameter in the male type is 9.2 mm., which gives a sectional area of 67 mm.² The rubber is radiopaque and only 0.8 mm. thick, which allows a very little loss of space due to the dead structures of the instrument. At a distance of 12 cm. from the tip this tube bears a second tube of a semilunar section only 6 cm. in length and of a cross-sectional area of nearly 24 mm.² These measurements have been calculated according to the Fanning equation for the turbulent flows in order to grant the same resistance to the air flow for both lumina:

$$\Delta p = \frac{2 f L V^2}{g D}$$

— friction coefficient
L — length of the tube
V — square of the velocity of the air flow
g — acceleration of gravity
D — diameter of the tube

The reduction in diameter of the smaller tube (designed for conducting the air to the right lung) is fully compensated for by the reduction in length. The smaller tube is connected to the larger one at a point where, when the latter is correctly placed in the left main bronchus, the former is exactly between the vocal cords. Consequently the small tube, or laryngeal tube, permits an air passage for the right side even in the case of a laryngeal spasm, and it constantly allows the same resistance as the contralateral tube. The small size of the laryngeal tube permits the very large diameter of the longer one.

[illegible] Milan, Italy.

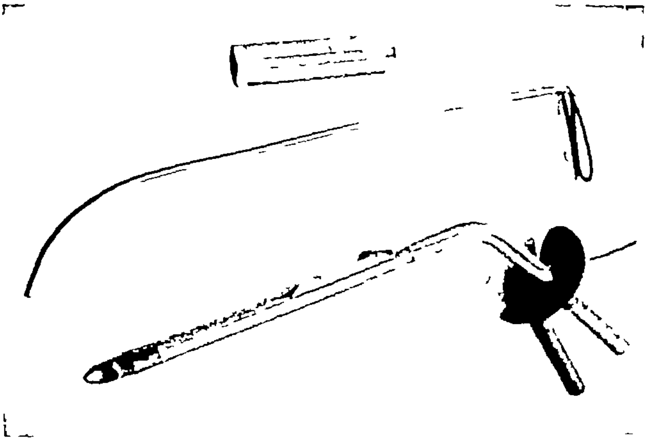

Fig. 1.—The instrument.

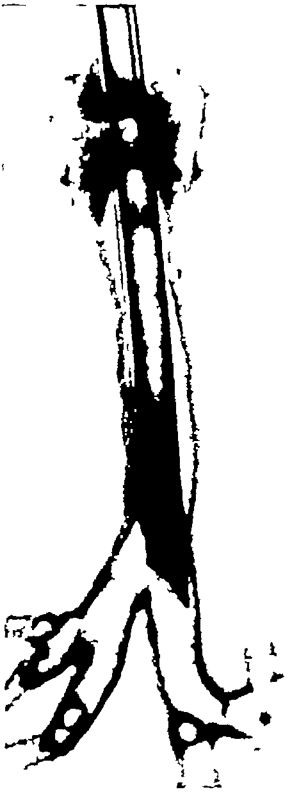

Fig. 2.

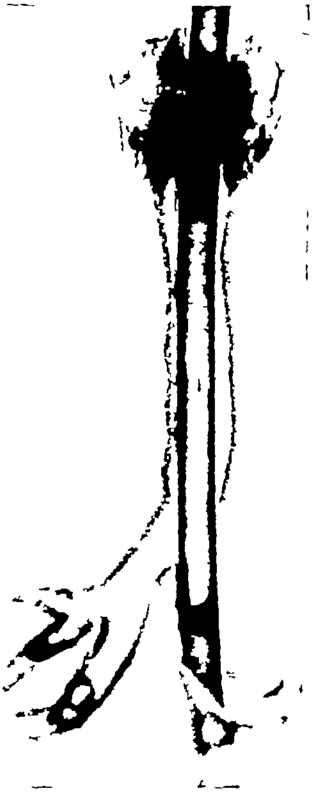

Fig. 3.

Fig. 2.—The action of the slope in position in the trachea.
Fig. 3.—The catheter in the correct position in the trachea.

Considering the diameter in its functional significance rather than in its geometric one it is like having a double lumen catheter made of two equal-sized tubes of 67 mm^2 each that is 134 mm^2 totally

This sectional area is much larger than that of all the other existing tubes for bronchospirometry In fact in the Zavod[6] and in the Gebauer[4] tubes the sum of the sectional areas is about 45 to 50 mm^2, in the Carlens[1] tube, about 80 mm^2 in the male size, in the Norris[5] about 45 mm^2 for the left variable for the right in my[2] single lumen catheter about 60 mm^2 variable for the right

Moreover during the intubation with this new catheter, some small spaces remain between the tube and the anatomic formations of the glottis which provide further space for the air flow of the right side These spaces are lost with the use of all double lumen catheters They are all that is conceded to the right side with the single lumen catheters In this new catheter they represent a useful complementary space to be added to the passage already granted by the laryngeal tube

The air coming from the right lung in the natural way finds at the level of the larynx the laryngeal tube by which it is conducted through the narrow passage of the glottis At the level of the pharynx it is again free and added to the air coming through the small spaces left around the tube is collected by a properly constructed mouthpiece at the level of the vestibulum oralis

A further device has been used to direct the catheter almost automatically to the left bronchus The tip of the catheter is cut at an angle of about 30 degrees The resulting slope slides on the tracheal carina and directs the tube toward the wanted side

Though the tube is made of a radiopaque rubber at the tip of it there is a metal ring which makes the radiopacity perfect and because of its peculiar form shows the correct position of the slope (Figs 2 and 3)

SUMMARY

A new catheter for bronchospirometry is described The instrument combines the advantages of the double lumen and the single lumen catheters

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AN UNUSUAL CASE OF BILATERAL DIAPHRAGMATIC HERNIA IN AN INFANT

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ALTHOUGH the literature contains numerous case reports dealing with surgical repair of single diaphragmatic defects,[1-5] it was thought worth while to report a case of bilateral diaphragmatic herniae in an infant recently observed at Milwaukee Childrens Hospital, for the following reasons:

1. The child had a short esophagus type of esophageal hiatus hernia, the defect occurring in the right hemidiaphragm.

2. A second defect was accidently produced in the dome of the *left* diaphragm during attempted surgical repair of the hiatus hernia elsewhere. It was this traumatic hernia which was responsible for the major complaints when the infant was seen here.

3. Successful surgical repair of both diaphragmatic defects was eventually accomplished in two stages on a debilitated infant. The first stage was mandatory as a lifesaving procedure.

CASE REPORT

D. K. was first admitted to Milwaukee Childrens Hospital on Dec. 29, 1949, at the age of 4 months. The chief complaint was vomiting of several weeks' duration. The vomiting was associated with abdominal cramps and borborygmi which were relieved by holding the baby in an upright position, and aggravated by horizontal positioning. Belching and flatulence were noted frequently.

The past history revealed that the female infant had been born at another hospital on Aug. 20, 1949. The birth weight was 7 pounds, 12 ounces. Because the child regurgitated feedings frequently, barium studies were done, and a short esophagus type of esophageal hiatus hernia was discovered. An attempt was made at surgical repair of the hernia at the age of 18 days, through a left transthoracic incision. Technical difficulties had made exposure of the esophagus almost impossible, and because of the precarious condition of the infant, the thorax was hastily closed without actual repair of the esophageal hiatus (which of course could not be visualized from the left side), and without lengthening of the esophagus. The baby was discharged from that institution in September, 1949, but returned in November, 1949, because of "cramps," vomiting, and failure to gain weight. There were subsequent bouts of diarrhea. Discharge after the second period of hospitalization was on Dec. 24, 1949, five days prior to admission to Milwaukee Childrens Hospital on Dec. 29, 1949.

Examination on entrance to this hospital revealed a "scrawny," wizened, dehydrated infant weighing 8 pounds, 9 ounces. (This represented a gain of only thirteen ounces in four months.) Skin turgor was poor and the eyes were sunken. There was no respiratory distress or cyanosis. A healed thoracotomy scar was seen on the left side over the course of the fifth rib. Dullness to percussion and diminution of breath sounds were noted over the lower left chest. The heart rate was regular with no audible murmurs.

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Initial laboratory data revealed a trace of albumin with occasional clumps of white blood cells in the urine. Leukocytes numbered 12,400 per cubic millimeter and the hemoglobin value was 12.5 Gm. per 100 c.c. of blood. A chest x-ray film taken on admission (Fig. 1) showed an esophageal hiatus diaphragmatic hernia on the *right* with approximately two-thirds of the stomach above the right diaphragm lying in the cardiophrenic angle. There was bowel in the *left* hemithorax and pneumonitis in the lung surrounding it. A portion of the left fifth rib had been resected.

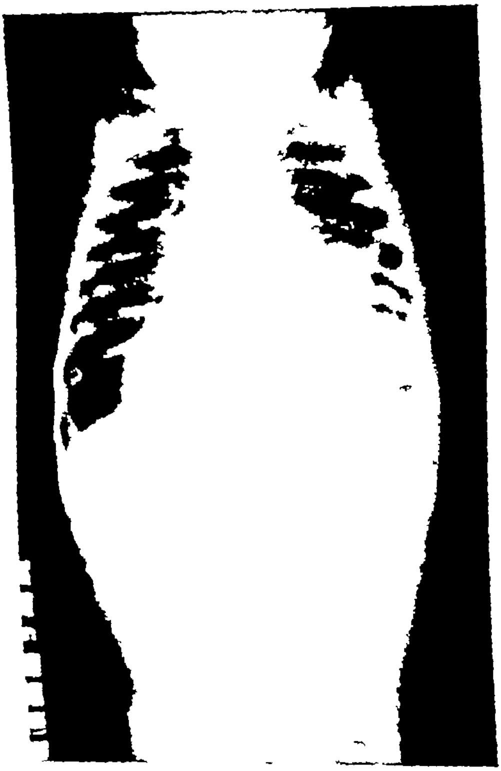

Fig. 1. Initial chest film showing herniated stomach in the right thorax and colon in the left thorax.

A barium enema substantiated the fact that a portion of the transverse colon lay above the left diaphragm (Fig. 2). Barium studies of the upper gastrointestinal tract revealed that the esophagus was situated in the right hemithorax and that the stomach herniated through an enlarged esophageal hiatus located in the right diaphragm (Fig. 3).

The defects in the two sides of the diaphragm were interpreted as being clearly independent of each other.

[illegible] the extreme rarity of bilateral diaphragmatic defects in infants, [illegible] films were obtained for comparison. It was seen that at birth the [illegible] had been intact but that there was a defect of the right dia[illegible] [illegible] remained relatively unchanged (Fig. 4).

[illegible] operation on the left was decided upon because it was felt that [illegible] and failure to gain weight were referable to incarceration of the colon, and that correction of this condition should be accomplished first.

First Operation.—Supportive therapy including penicillin for the pneumonitis, and whole blood for the anemia and hypoproteinemia was given to rehabilitate the infant. On Jan. 17, 1950, left thoracotomy was done. A long segment of rib nine was resected subperiosteally for exposure. The roentgen interpretation was corroborated by the discovery that the major portion of the transverse colon had herniated through a small opening in the dome of the left diaphragm. Many adhesions to pleura, lung, and diaphragm were freed before the colon could be returned to the abdomen. The bowel and its mesentery were edematous and purplish in color, but became normally pink upon being freed. There was no hernial sac. The defect, approximately 2 cm. in diameter, was sutured and imbricated with No. A cotton mattress sutures. There was no esophageal hiatus in the left diaphragm and neither stomach nor esophagus could be visualized from the left approach. The thorax was closed in layers without drainage after re-expansion of the lung. The infant's immediate postoperative condition was only fair with moderate transitory cyanosis for which oxygen therapy was given. The child's temperature rose to 103.2° F. on the evening of the first postoperative day but progress thereafter was satisfactory. Small feedings were given and retained on the second postoperative day.

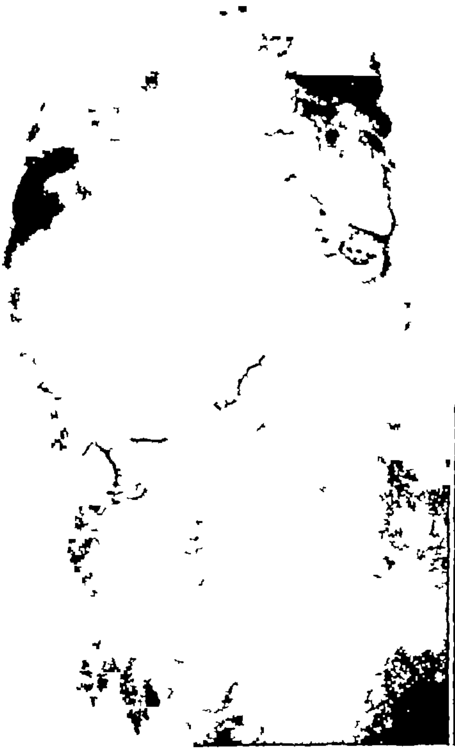

Fig. 2.

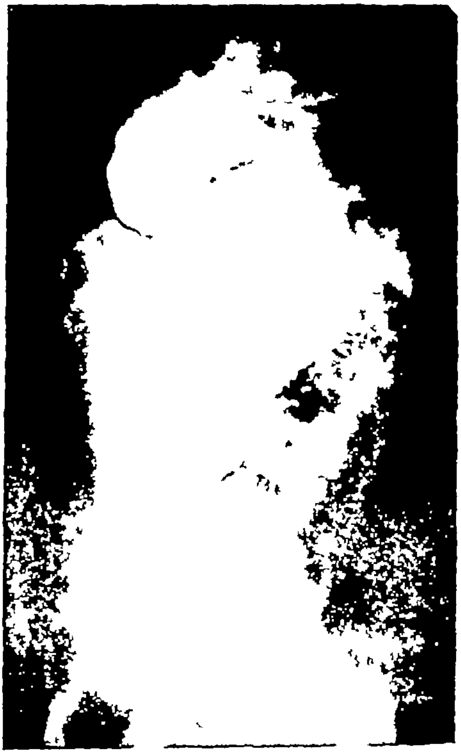

Fig. 3.

Fig. 2.—Barium enema showing colon in the left thorax.

Fig. 3.—Stomach filled with barium demonstrating herniation of two thirds of the organ into the right chest.

This hernia was interpreted as traumatic in origin because it was not present on the original films and because of its location in the fibrous dome. This area is not a fusion point, and, as has been pointed out by Harrington,[6] herniation at this point must be regarded as traumatic in origin.

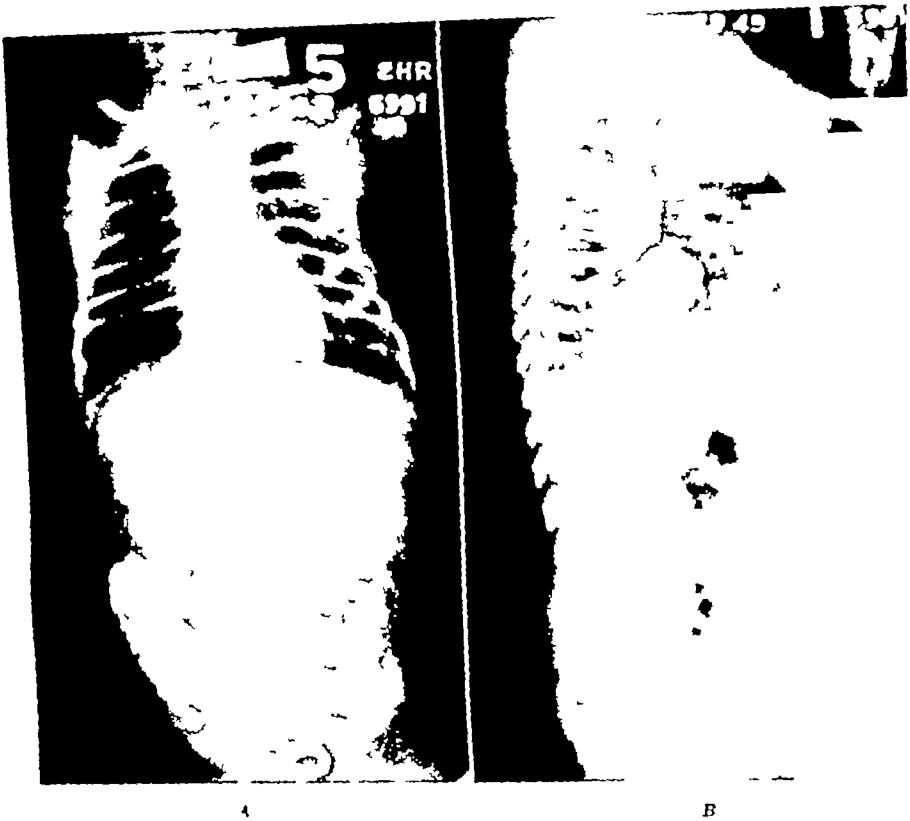

Fig. 4.—A, Original stomach films taken elsewhere showing herniation of the stomach into the right chest but no evidence of herniation of the colon into the left. B, Same lateral view.

Fluoroscopy of the stomach and colon performed on Jan 28 1950 the tenth postoperative day showed no change in position of the esophagus and stomach. The colon and small intestine were now seen to be in the abdomen below the diaphragm. The left thorax was clear (Fig 5). The patient was discharged from the hospital on the fourteenth postoperative day taking feedings well and gaining weight. There was no respiratory difficulty. Regurgitation of portions of feedings occurred if the child was placed in the prone position immediately after feeding. Bowel function was restored to normal following this stage with disappearance of diarrhea, hyperperistalsis and anorexia and establishment of one to three normal bowel movements daily. It was deemed advisable to postpone consideration of further surgery until the child had gained weight and strength.

The second admission date was Nov 15 1950 when the child was 14 months old. The interval history indicated that the child had done well since the last operation. Multiple small feedings were required to prevent regurgitation. There had been a two pound weight gain since discharge from previous hospitalization. Physical examination revealed normal findings. Repeat fluoroscopy of the esophagus and stomach showed no change. Because the esophagus was somewhat tortuous, it was felt that it could be sufficiently mobilized to allow placing the stomach entirely under the diaphragm and to allow repair of the diaphragmatic defect.

Fig. 5.—*A*, Colon x-ray photograph following first operation showing complete reduction of the hernia on the left; colon completely in the abdomen. *B*, Stomach x-ray film following the first operation showing no change in the herniation of the stomach through the right diaphragm.

Preoperative penicillin therapy was given, and on Nov. 21, 1950, under endotracheal gas ether anesthesia, a right thoracotomy was performed through the bed of the resected ninth rib. There was a free pleural space, and it was seen that at least three-fourths of the stomach, enclosed in a hernial sac, lay above the diaphragm. The sac was incised and the entire circumference of the esophagus freed from the esophagogastric junction to a point 3 cm. proximally. The stomach could then be replaced into the peritoneal cavity. The diaphragmatic defect was closed about the esophagus with interrupted 00 cotton sutures. Mediastinal and diaphragmatic pleurae were utilized to cover raw surfaces and to reinforce the suture line. The lung was re-expanded and the wound closed in layers with interrupted cotton sutures. It was thought that this hernia was definitely congenital in origin.

The postoperative course was uneventful except for vomiting for two days; this was controlled by gastric suction. Penicillin therapy was continued for six days. Feedings of water and formula were begun on the third postoperative day Barium swallow on the tenth postoperative day revealed a slightly dilated esophagus with the stomach lying entirely under the diaphragm (Fig 6) The child was discharged on the seventeenth postoperative day

Subsequent fluoroscopy in October 1951 demonstrated that both diaphragmatic defects remain closed The child has continued to gain weight and is free of symptoms on a normal diet (Fig 7)

Fig 6

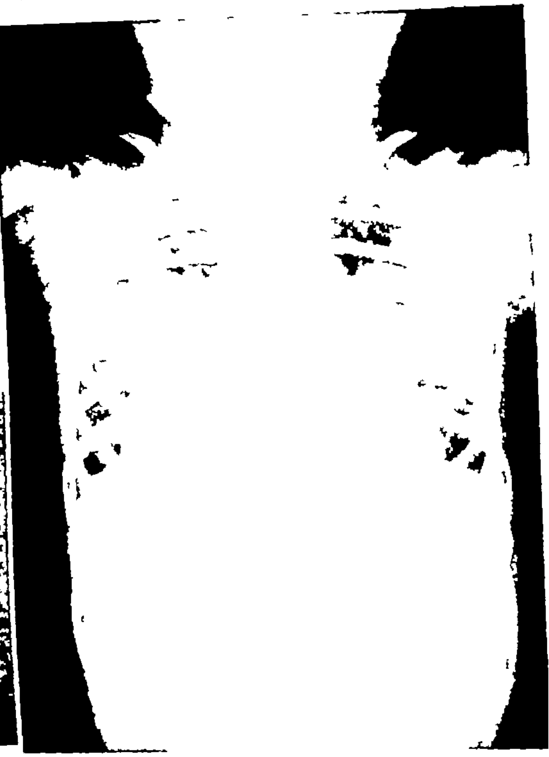

Fig 7

Fig 6 —Stomach x ray film following second operation showing dilatation of the esophagus but no hiatus hernia

Fig 7 —Posteroanterior chest film following second operation showing essentially normal chest

DISCUSSION

When the infant was first admitted to this hospital the clinical picture was that of partial bowel obstruction dehydration and inanition An initial attempt was made to improve the nutritional status of the patient by careful small oral feedings supplemented by parenteral fluids and whole blood It became apparent after nineteen days of this type of treatment that definitive surgical therapy was mandatory in spite of the poor condition of the child Since the symptoms appeared to be primarily referable to incomplete bowel obstruction and since the radiologist was reasonably certain that there were two diaphragmatic defects it was felt that correction of the left hemidiaphragmatic defect was urgent Following the first stage there was such a noticeable clinical improvement in the infant that consideration of surgical repair of the esophageal hiatus was deferred until such time that an appreciable weight gain had [illegible] and the child had reached some degree of development commensurate with its age It was not even established at this time that the esophagus was of sufficient length to permit placement of the stomach in the abdominal cavity and it was felt that existence of a short esophagus type of esophageal hiatus hernia was not a threat to life, nor near normal development, witness the fact that many adults with this type of deformity lead almost normal lives

Barium studies were repeated in an attempt to determine whether sufficient length of esophagus could be developed to place the stomach into the abdomen below the diaphragm, and it was finally decided that the tortuosity of the esophagus indicated that such length could be developed Continued regurgitation of formula, although small in amount, was of sufficient severity in our judgment, to warrant an attempt at repair of the defect

It has always been our conviction that the transthoracic approach is preferable to the abdominal route in all but foramen of Morgagni types of diaphragmatic herniae In this particular instance sharp dissection was required bilaterally to free the bowel and stomach from the lung sufficiently to allow replacement of these organs into the abdominal cavity This was accomplished easily under direct vision whereas we believe such dissection would have been difficult from an abdominal approach This was particularly true on the left side since the defect was small and exposure from the abdominal side would have necessitated enlarging the defect considerably On the right side, mobilization of the esophagus was also easily accomplished under direct vision in contradistinction to the blind traction which would have been necessary from an abdominal approach particularly since mobilization and retraction of the right lobe of the liver would have been required

The failure of the child to gain weight demonstrates the necessity for early repair when bowel is contained in the defect In this case the vascular supply to the colon was impaired as evidenced by thickening and edema of the bowel wall which contributed to the degree of obstruction of bowel lumen

Careful radiographic studies are essential to determine the type of defect and amenability to surgical repair In this instance such studies established first that there were bilateral diaphragmatic defects and later that there was probably enough esophageal length to permit repair

CONCLUSION

1 An unusual case of bilateral diaphragmatic herniae in an infant is presented

2 The advantages of the transthoracic approach are enumerated

3 The need for early surgical repair is emphasized

4 The importance of careful preoperative radiographic studies is stressed

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LOCALIZED PULMONARY HYPERTROPHIC EMPHYSEMA

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LOCALIZED pulmonary hypertrophic emphysema unassociated with an aspirated foreign body or tenacious mucus from an acute respiratory infection is an unusual condition which was barely mentioned in the medical literature prior to 1949 This disease usually occurs in infants and young children although two cases discovered in the fourth decade of life have been reported The exact etiology of the disease has not been established with certainty but it appears reasonable to assume that it is congenital in origin The diagnosis can usually be made radiologically if the existence of this entity is kept in mind Surgical extirpation of the diseased pulmonary tissue appears to be strongly indicated The following case report illustrates the diagnosis and management of pulmonary hypertrophic emphysema involving segments or portions of segments of the posterior segment of the right upper lobe and the superior and lateral basal segments of the right lower lobe in a 10 year old white boy

CASE REPORT

F G a 10 year old white boy, was first seen on Feb 1, 1952, at which time a chest x ray picture showed marked emphysema of the right lung * When first seen the patient had recently recovered from a *respiratory infection* A chest film had been ordered by his physician to determine if any pulmonary pathology was present The patient gave an equivocal history of possible recent foreign body aspiration The films (Figs 1 and 2) were interpreted as showing obstructive emphysema caused by a nonopaque foreign body in the right bronchial tree He was admitted to the St Francis Hospital, Lynwood, where bronchoscopy was performed *This revealed an entirely normal tracheobronchial tree*

Following this procedure, a right Lipiodol bronchogram was performed on Feb 6, 1952 and showed what was *interpreted as a large air filled, cystic area in the postero lateral lung field* (Figs 3 and 4)

A right thoracotomy was performed on Feb 13 1952 at which time three separate areas of pulmonary emphysema involving the posterior segment of the right upper lobe, the superior segment of the right lower lobe and the lateral basal segment of the right lower lobe were found The emphysematous areas compressed the normal pulmonary tissue An artist s conception of the operative findings is shown in Fig 5

Inasmuch as there was some doubt as to whether entire segments were involved it was thought feasible to attempt *resection from the periphery inward* The line of demarcation with the normal lung was quite clear A pleural incision was made around the periphery of the emphysematous area in the superior segment of the right lower lobe [illegible] with gauze pledget dissection the intersegmental plane was easily developed [illegible] vessels were divided between mosquito clamps and ligated with fine silk [illegible] at the hilar aspect of the emphysematous area The bronchus to the [illegible] area was about 2 mm in diameter this was closed with fine silk The other

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[illegible] March 2 [illegible]

* [illegible] Calif

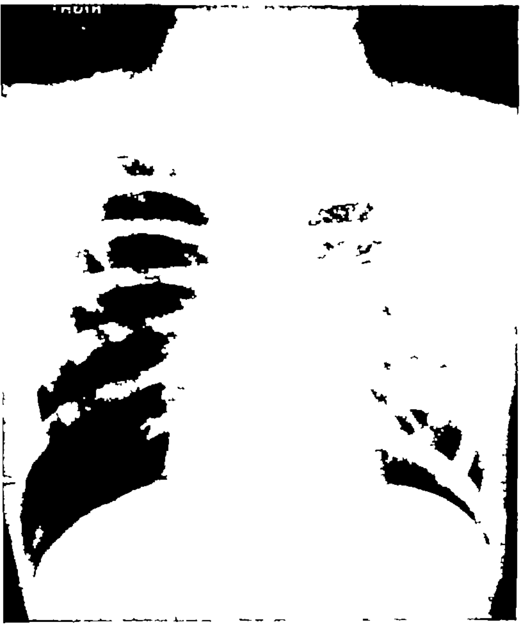


Fig 1

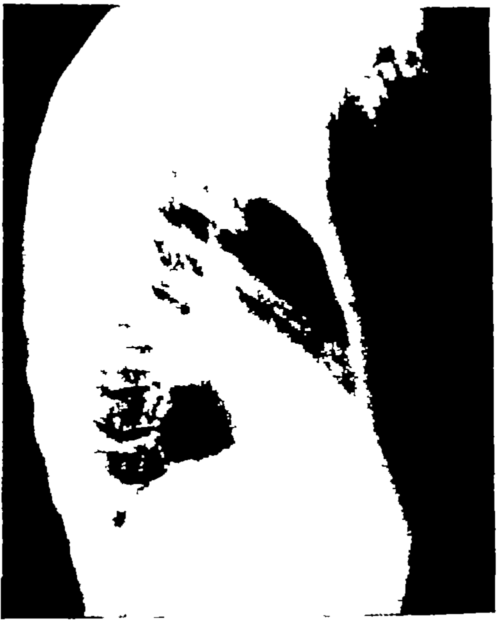


Fig 2

Fig 1—Posteroanterior view of chest showing emphysema of the right lung
Fig 2—Right lateral view of chest.

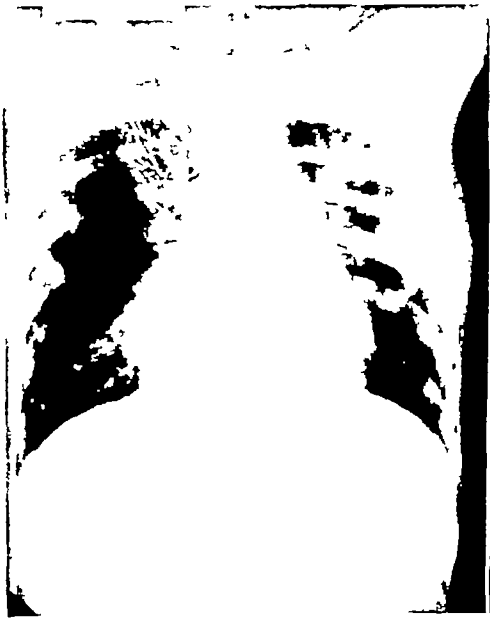


Fig 3

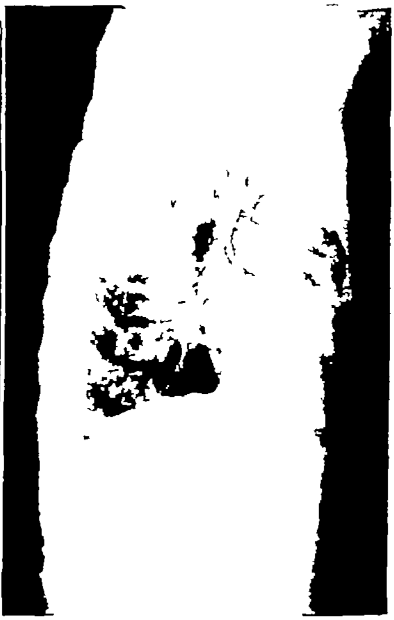


Fig 4

Fig 3—Posteroanterior view of Lipiodol bronchogram showing area of emphysema
Fig 4—Right lateral view of Lipiodol bronchogram showing area of emphysema

two areas were then removed by a similar technique Raw pleural surfaces were then closed with continuous fine catgut sutures to minimize air leaks The middle lobe was anchored to prevent rotation and atelectasis At the conclusion of the procedure there was satisfactory expansion of the lung with minimal air leaks As the right lung did not entirely fill the pleural cavity the phrenic nerve was crushed at the diaphragm to help de-

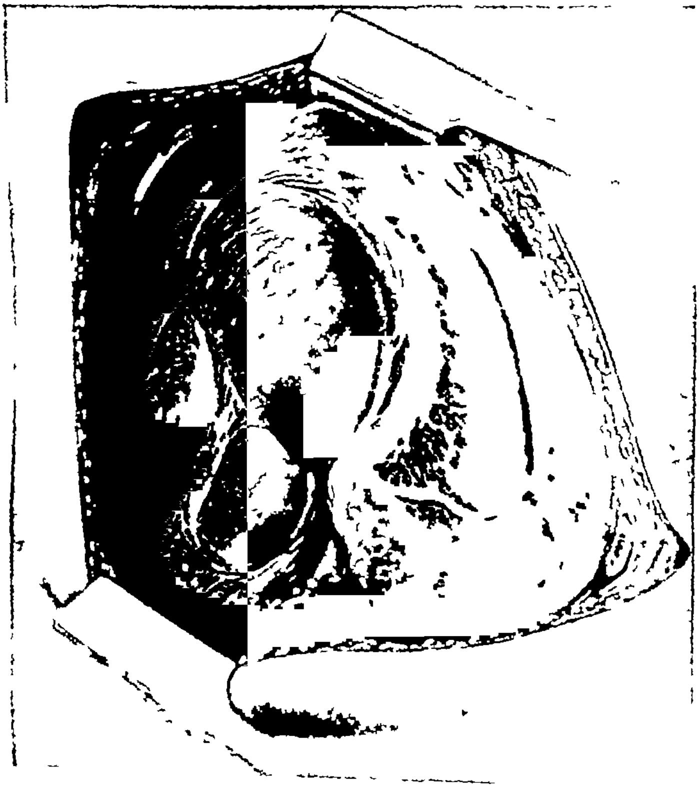
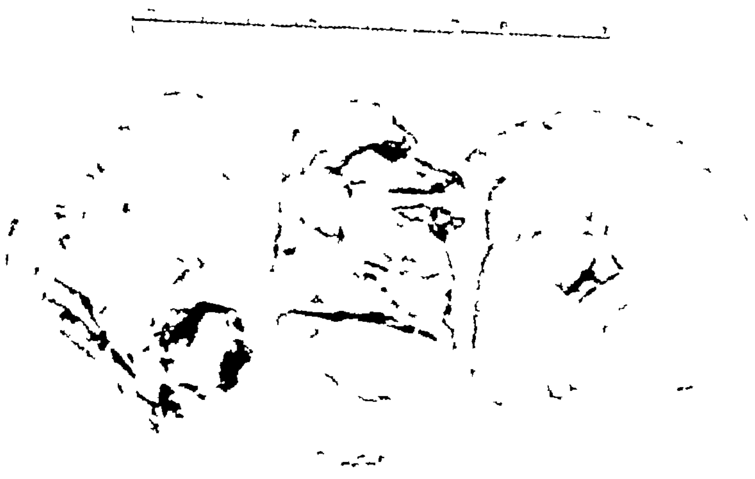


Fig [illegible] —Artist's conception of operative findings



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crease the size of the pleural cavity Two intercostal catheters were connected to water seal drainage The patient had an uncomplicated postoperative course, and was discharged on the eighth postoperative day

Photographs of the formalin hardened segments are shown in Fig 6 Microscopic sections of the surgically removed areas showed pulmonary emphysema, chronic bronchitis, and interstitial pneumonitis Fig 7 is a photomicrograph showing the emphysema

The patient's progress has been followed for over a year, and he is entirely well The right diaphragm is functioning The vital capacity has increased from a preoperative reading of 1 7 L to a recent postoperative reading of 3 L A review of the patient's history revealed possible asthma prior to a tonsillectomy at the age of 3½, but none following this procedure He was never allergic to any material except possibly barber's talc

The most recent postoperative film of the chest is shown in Fig 8

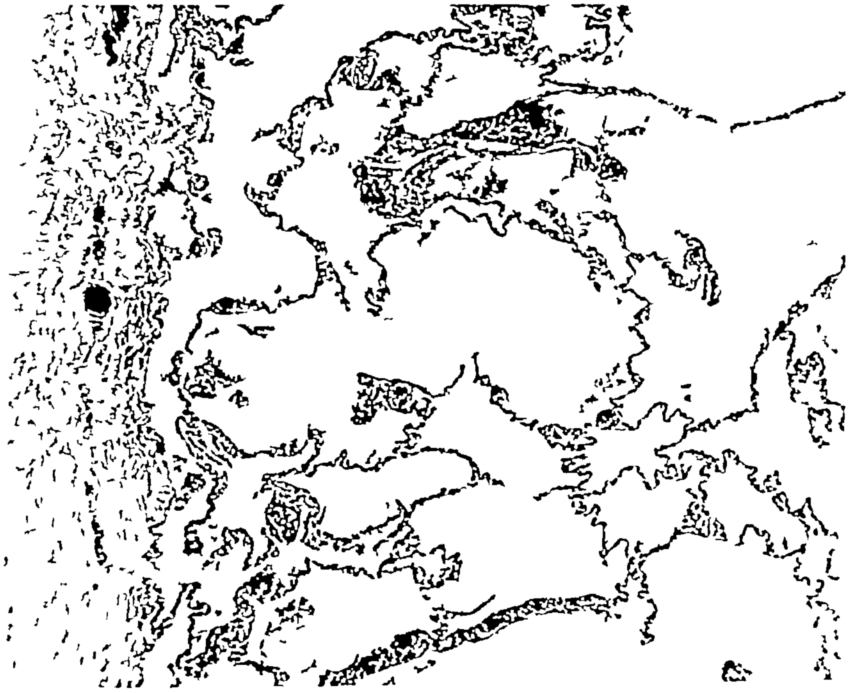

Fig 7—Photomicrograph showing emphysema typical of all specimens

DISCUSSION

Historical—The first recorded case was that of Royes[1] in 1938 He reported a large area of hypertrophic emphysema involving a portion of the right middle lobe discovered during an autopsy on a 39 year old man who died following an accident Royes found a flap of mucosa which partially occluded the bronchus to the affected area

Leahy and Butsch in 1949 reported a case involving the left upper lobe in an 11 week old white boy This infant had marked respiratory distress from birth A bronchoscopy was performed which was negative Thoracotomy was performed with a preoperative diagnosis of probable cystic disease of the lung. At operation a markedly distended left upper lobe and a collapsed lower lobe were noted. Left upper lobectomy was performed and the patient recovered.

Sweet,[3] in 1950, reported a case involving the left upper lobe in a 34-year-old man. The presenting complaint was dyspnea on exertion which had been present for twenty years. A left pneumonectomy was performed. In addition to the emphysema, sarcoidosis was present in the hilar glands as well as in the pulmonary tissue. This patient recovered.

Robertson and James,[4] in 1951, reported five cases of emphysema which they felt was congenital in origin and in which the emphysema involved an entire lobe. They felt the emphysema was caused by folds of mucosa, or weakness of the bronchial wall forming a check-valve mechanism. The infants ranged in age from 2 weeks to 11 months; three cases had involvement of the right upper lobe, one the right middle lobe, and one the left upper lobe. In three cases in which lobectomy was performed all patients recovered; the other two patients not operated on died.

Fig. [illegible] Posteroanterior view of chest taken four months postoperatively.

Shaw, in 1952, reported two occurrences: one in a 4-year-old child involving the subapical segment of the left upper lobe, in which a segmental resection was performed with recovery, and one in a 7-week-old infant involving the right middle lobe, in which a middle lobectomy was followed by recovery of the patient.

[illegible] in 1952 reported a case involving the right middle lobe of a 17-[illegible] old infant; a middle lobectomy was followed by the recovery of the patient.

Diagnosis.—Most of the other recorded cases of localized pulmonary hypertrophic emphysema occurred in infants. The initial impression in this case, as in Williams's case,[6] was that the patient had obstructive emphysema caused by an intrabronchial foreign body and bronchoscopy was carried out in an effort to remove the suspected foreign body. Lipiodol bronchogram following the bronchoscopy was of great assistance in determining the need for thoracotomy. If the possibility of localized pulmonary hypertrophic emphysema is borne in mind the correct preoperative diagnosis is possible.

Pathology.—Shaw[2] has given an excellent description of the pathology. He states that "the diseased segment is enlarged to many times its normal volume in a uniform dilatation of the air sacs. The bronchi, arteries, and veins are much smaller than one would expect to find supplying a segment of lung. Even when the bronchi are opened and the segment of lung tissue is removed from the body it does not collapse appreciably. It is uniformly pink in color even in adults, indicating that it has not taken part in the usual ventilation of lung tissue. Except for the pink color, it more closely resembles Gelfoam than any other substance. Several hours after being removed from the body this tissue will float upon water with less than a tenth of its volume being submerged. Microscopic examination of the tissue reveals air sacs and alveoli that are generally distended and empty. The intervening septae are thin and there is no inflammatory reaction. The blood vessels are small and have thin walls. The bronchioles are empty. The bronchial mucosa is normal except for slight chronic inflammatory infiltration. The cause of the emphysema is not evident in the examination of the specimens."

In the present case microscopic sections showed evidence of chronic bronchitis. During the two weeks that the patient was under observation prior to thoracotomy, he was afebrile, had a normal blood count, and no respiratory symptoms other than dyspnea on exertion. No further areas of emphysema have developed at the present time, more than one year after surgery. At operation the abnormal lung tissue was extremely soft and spongy. The color was pale pink, it did not deflate on releasing endotracheal pressure, and no emphysematous blebs were noted on the pleural aspect.

Etiology.—This condition should not be confused with regional obstructive emphysema in infants and children caused by thick viscid mucus as a result of acute respiratory infections.

Caffey,[7] in 1940, reported seven cases of this type of emphysema associated with acute respiratory infections in which cystic dilatations could be seen in roentgenograms and which returned to normal with nonoperative treatment.

Obstructive emphysema of a lobe or a lung is commonly caused by an aspirated foreign body.

In the particular type of emphysema under discussion most of the previous authors feel, as I do, that it is congenital in origin. Folds of mucosa producing valvelike mechanisms in the bronchus, compression of a thin walled bronchus by an adjacent pulmonary vessel, and localized bronchial chondromalacia have all been described as the underlying cause No definite conclusions as to the etiology can be drawn from this case

SUMMARY

Multiple resection from the periphery inward in a 10-year-old boy having pulmonary hypertrophic emphysema localized to segments or portions of segments of the posterior segment of the right upper lobe superior segment of the right lower lobe and lateral basal segment of the right lower lobe is reported This is apparently the tenth recorded case of localized pulmonary hypertrophic emphysema occurring in infancy or childhood two other examples were reported in adults Surgical excision appears indicated in this condition

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VARIATIONS IN PULMONARY VASCULAR PRESSURES

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AN ABNORMAL type of pressure wave was observed during the course of an experiment wherein the "pulmonary capillary" pressure was being measured as suggested by Hellems and his associates.[1] This pressure wave grossly resembled an intrapleural pressure curve. Autopsy of this animal confirmed the presence of the catheter in the peripheral arterial vessel but immediately raised questions as to both the significance of this experimental method and the validity of the pressure values secured. Pressure measurements were then made in various vessels of the thorax accessible by the catheterization procedure being employed in anticipation that the information obtained would at least partially resolve doubts about the method.

METHODS

Mongrel dogs were anesthetized with Nembutal, 30 mg. per kilogram intravenously. Catheters, No. 7 or No. 9, were passed under fluoroscopic visualization. Two catheters were placed on the left side, one in the aorta or left ventricle and the other in the left atrium or one of the pulmonary veins. Similarly on the right side one catheter was positioned in the pulmonary artery and another was wedged in a peripheral pulmonary arterial branch as described by Hellems and his associates.[1] In some instances a femoral artery was also cannulated. Patency of the catheters was assured by slow infusion or an occasional flushing with heparinized saline. Pressures were recorded simultaneously by means of Statham strain gauges and Sanborn or Brush oscillographs. Following a series of measurements at the above described positions, one or more catheters were moved so as to obtain records from additional places in the heart or adjacent vessels. This maneuver permitted the securing of various combinations of records from the right and left sides within a few heart beats. Usually the catheters were moved while the recordings of pressure were being made continuously and their positions then checked fluoroscopically. In several instances the catheter positions were confirmed at autopsy.

RESULTS

A large number of records was obtained from nine dogs on eleven occasions. A summarization of pertinent data obtained from these records is presented in Table I and some tracings are reproduced in Figs. 1 and 2. The pressures obtained from the left atrium, pulmonary veins, and "pulmonary

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TABLE I. PRESSURE RELATIONSHIPS IN VESSELS OF THE THORACIC CAGE*

	FEMORAL ARTERY		AORTA		LEFT VENTRICLE		LEFT ATRIUM	PULMONARY VEIN		PULMONARY CAPILLARY†	PULMONARY ARTERY		RIGHT VENTRICLE		RIGHT ATRIUM	
	SYS	DIAS	SYS	DIAS	SYS	DIAS	MEAN	SYS	DIAS	MEAN	SYS	DIAS	SYS	DIAS	SYS	DIAS
							5.0			4.7	10	5				
							2.7			5.8						
			133	120	170	5	1.5	7.5	3.0	3.4	15	8	18	−1	−1.5	−2.5
	180	120	118	115	150	1	3.0	10.5	5.0	3.5	13	6	13	1	0.6	−0.5
	152	108	135	125	158	7	3.0	11.0	4.0	2.0	32	8	31	−1	1.0	1.0
			128	105	165	11	4.0	4.0	3.2	3.0	10	4	12	1	1.0	1.0
							9.0	12.0	9.0	9.0	15	7	15	0		
			110	119	160	5	7.5	11.0	11.0	8.0	11	8	15	−1	2.5	−1.5
			130	115	110	5	6.0	8.0	0.9	6.0	15	7	18	2	2.0	−2.0
			131	110	111	4	5.0	12.0	8.0	8.0	20	10	20	0	7.0	3.0
	105	70					5.0	10.0	4.0	7.0	12	4	12	1		
Mean			118	110	156	6	4.7	10.1	4.0	5.5	15.6	6.7	17.1	0.2	2.1	−0.8

* All pressures are expressed in mm. Hg; eleven experiments.
† Wedged pulmonary artery.

capillary" are of greatest interest. The mean left atrial pressure exceeded the mean "pulmonary capillary" pressure by some 0.8 mm. Hg, but this relation was not consistently evident in individual cases. In three instances, a higher value was observed in the left atrium than the pulmonary capillary by 0.3 to

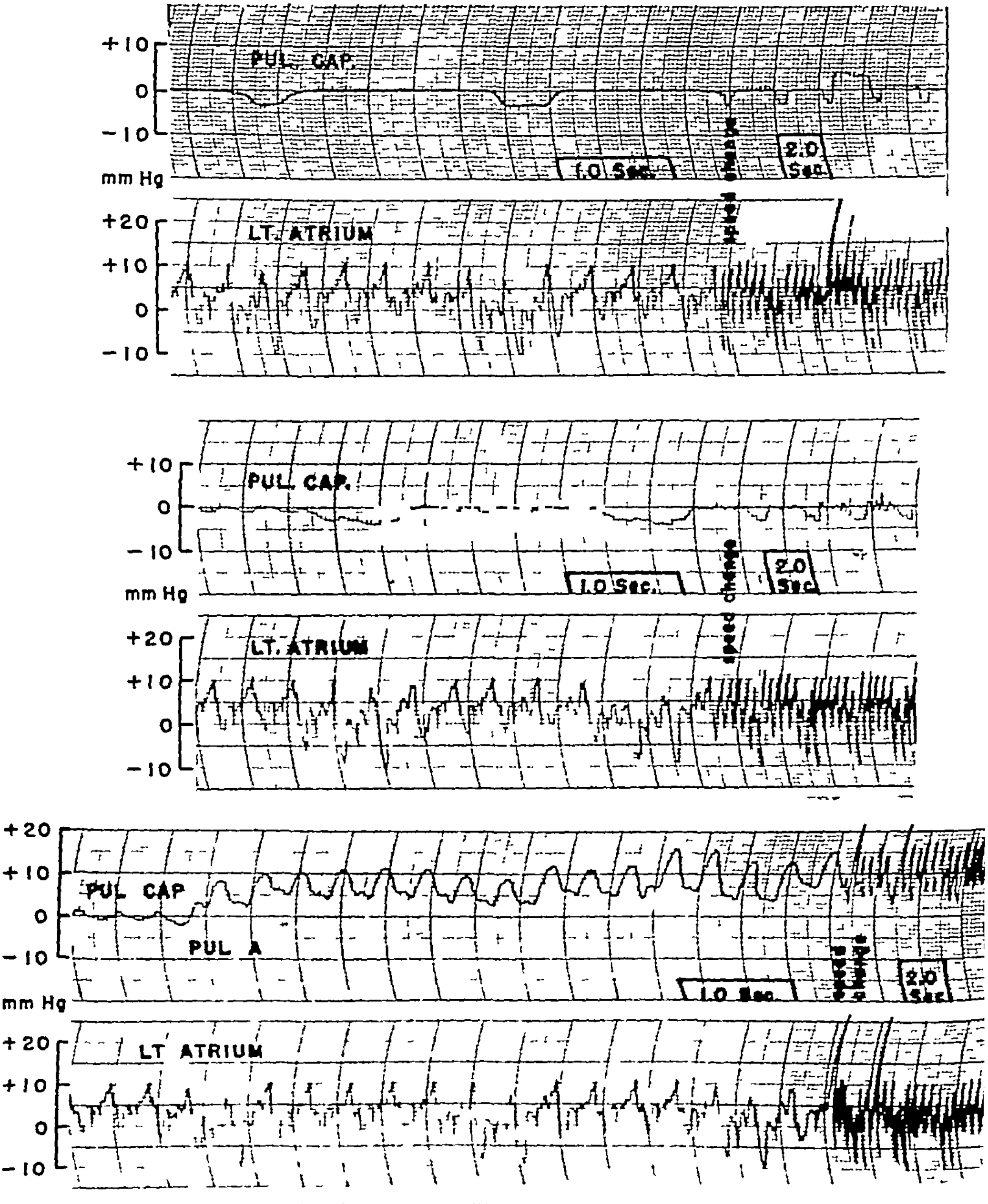

Fig. 1.—A type of pulmonary capillary pressure sometimes observed is illustrated. The lowest record shows the transition to pulmonary arterial pressures as the catheter was being withdrawn. The left atrial pressure is presented for reference.

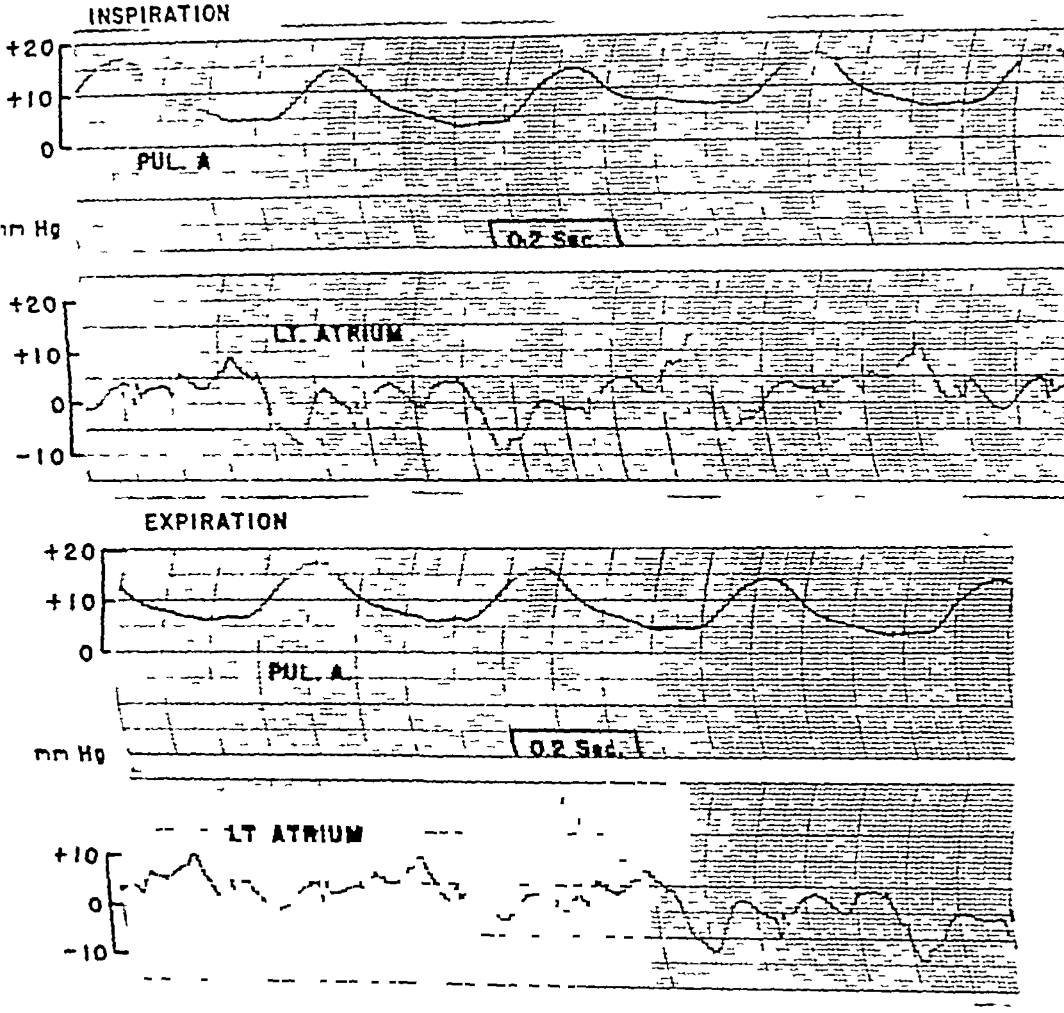

Fig. 2.—[illegible] rating pattern of left atrial pressure tracings with pulmonary [illegible]

10 mm Hg. On two occasions the pressures were equivalent while in the remainder the pulmonary capillary values exceeded those observed in the left atrium by [illegible] to 0.[illegible] mm Hg.

Although these differences are small and the technical difficulties of recording great, some doubt is held concerning the validity of using 'wedged catheter pressures' as representative of left atrial pressure. On three occasions a record similar to that shown in Fig. 1 has been obtained. In each instance the catheter was positioned in a vessel in the lower border of the [illegible] lung field. Can the recorded pressure be considered a pulmonary capil[illegible] [illegible]? It appears to be a record of intrapleural pressure with [illegible] possible when the catheter was in this position. Slow [illegible] the catheter from this position eventually resulted in a pressure tracing somewhat similar to that of a "pulmonary capillary" pressure. However, in Fig. 1 the transition to a modified pulmonary arterial pressure is too rapid to permit positive identification. When a catheter is wedged as far out in the periphery of the lung as these were, the rapid injection of 1 ml. of saline induced a marked elevation of pressure which persisted for several minutes before it gradually returned to its former level. Autopsy observations failed to show any injury to vessels or lung tissue as a consequence of this procedure.

The pressure tracings (Fig. 2) obtained from the left atrium through a catheter going down the carotid artery and lying within the left atrium are somewhat similar in form to those published by Ankeney,[2] but the instantaneous pressure values are somewhat different. There are a number of negative values on the curve, especially noticeable during inspiration. Although some artifacts may be present due to catheter vibrations of intracardiac origin, they are still suggestive of pressure alterations occurring in the intact closed chest animal.

Pressures measured when a catheter is apparently wedged into a pulmonary vein were invariably greater than simultaneous measurements of pulmonary capillary and are similar to the pulmonary arterial pressures. However, artifacts prevented accurate determinations of points of similarity in the two curves.

DISCUSSION

The occasional observation of an intrapleural type of pressure wave when a catheter is wedged into a distal pulmonary artery was an unexpected finding. Animals in which the phenomenon was observed were narrow chested and the catheter was placed far out into the diaphragmatic border of the lung field. The small mass of tissue present at this point may have permitted the transmission of intrapleural pressure variations but it is inconceivable how such an event could occur in view of the pressure gradient theoretically existing. Regardless of the causative factors leading to such pressure tracings, their occurrence does suggest that "pulmonary capillary pressures" must be evaluated with considerable caution.

Pulmonary capillary pressures slightly higher than left atrial pressures as observed in this study are in general agreement with the similar, although greater differences reported by Ankeney[2] in the open chest dog. Gorlin and his co-workers[3] however, were unable to find any significant differences in pressure between these two sites and suggest that within the error of measurement the values are equal. Weissel and his associates,[4] Lagerlof and Werko and Cournand[5] have, on the basis of studies made in cases with atrial septal defects, expressed doubt as to the pressures recorded by the method of wedging being "capillary pressure" and implied that it may represent a modified pulmonary venous pressure.

However, Calazel and his fellow workers were unable to obtain pressure curves suggestive of this venous character by obstructing a peripheral pulmonary artery in five of their six patients. The pulmonary capillary pressure curves obtained in the present study cannot be used to confirm or deny these observations since in the majority of instances they were essentially flat waves with minor and inconstant phasic variations. This does not, however, preclude the possibility that a manometric system consisting of pulmonary capillaries and venules is formed when the catheter is wedged in a suitable peripheral pulmonary arteriole. The reverse manometer system (pulmonary capillary-arteriole) formed when a catheter is wedged into a pulmonary vein postulated by Lagerlöf and Werkö of capillaries and arterioles appeared to be present in the study being reported. The pulmonary venous pressures (PCA) were higher than those observed in the left atrium but lower than those of the pulmonary artery. These findings agreed also with those reported by Weissel and his associates[4] but are in contrast to the results of Hellems and his associates who found identical mean values on both sides of the capillary bed.

SUMMARY AND CONCLUSIONS

The determination of "pulmonary capillary pressure" is not a simple matter of obtaining a pressure recording while a catheter is wedged into a peripheral pulmonary artery. If the catheter is wedged into a suitable arterial vessel, respiratory pressure variations similar to intrapleural pressures may be recorded. The possibility that under certain circumstances "pulmonary capillary" pressures really represent pulmonary capillary-venule pressures cannot be ignored since pressures recorded from a wedged pulmonary vein were of such magnitude as to indicate the possibility of the establishment of a pulmonary capillary-arteriole manometric system.

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BILATERAL GRANULOMA OF THE LARYNX DUE TO INTRATRACHEAL ANESTHESIA

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THE administration of anesthesia by way of an endotracheal tube has repeatedly been recognized as one of the major advances in anesthesia and thoracic surgery. It allows the anesthetist to maintain the patient in a state of "physiologic safety" by reason of this endotracheal anesthetic technique.

It has always been amazing, however, that patients do not have more laryngeal difficulty. The laryngeal tissues have always been recognized as delicate and extremely sensitive. It would be suspected that the passage of a rubber tube through these delicate sensitive tissues followed by the rather prolonged contact with this foreign body would result in a certain amount of irritation. The most skillful intubation could not logically be expected to remove all the factors that have to do with laryngeal irritation. The incidence of mild traumatic postoperative laryngitis is not known. Individuals exhibiting voice changes or "sore throat" following endotracheal anesthesia are known to all of us, but the frequency is not a matter of record. Tracheal web formation has been reported in the *New England Journal of Medicine* as a result of intubation.[2]

Trauma to the vocal cords of enough intensity to cause formation of granulomatous lesions is a rare occurrence. In the present literature there are twenty-three cases reported, of which thirteen were bilateral granuloma and ten were unilateral granuloma. Curiously enough, in one series of ten cases, nine were reported to be in women.[1] The case reported here also occurred in a woman. This sex predominance may mean that women have smaller voice boxes (could overuse be a cause of hypoplasia?) or the tissues are more delicate.

CASE REPORT

Mrs. D. S., a 28 year old woman, was a patient at the Arizona State Sanatorium. A right upper lobectomy for tuberculosis was performed on Dec. 9, 1950. The anesthesia time (from intubation to extubation) was four hours and twenty minutes. After surgery she complained of a sore throat and her voice was hoarse. The hoarseness persisted and eight weeks following lobectomy, direct laryngoscopy revealed polypoid tumor masses on either vocal cord. The granuloma of the right vocal cord was somewhat larger, so it was removed first. Fourteen days later the polyp was removed from the left vocal cord.

The pathologic examination and report by Dr. Harold Wood was identical in each instance. "The gross specimens consist of small bits of gray brown tissue which vary from 0.2 to 0.6 cm. in diameter. The microscopical examination reveals a very active polypoid growth of vascular granulation tissue, which is superficially ulcerated and inflamed. It contains mitoses and simulates a capillary hemangioma or granuloma pyogenicum. There is no evidence of malignancy. Diagnosis: A polypoid capillary hemangioma or a very vascular laryngeal polyp."

Received for publication May 11, 1953.

With reference to the intubation and anesthesia in this patient the co-author (A G U) comments as follows 'The intubation was not traumatic and exposure of the larynx and insertion of the tube was done without difficulty Pentothal Sodium nitrous oxide and curare were used After the initial depth of anesthesia for intubation the patient was maintained in plane one During the last hour she was maintained so lightly in plane one that she swallowed and coughed occasionally She was awake talked and was oriented in the operating room immediately after the tracheobronchial toilet Undoubtedly the too light anesthesia during the last hour with the motion of the larynx over the tube due to swallowing and coughing is the trauma responsible for the production of the granulomatous tissue

The patient was discharged from the sanatorium three and one-half months following lobectomy and one month after removal of the second granuloma On discharge from the sanatorium the vocal cords had a normal appearance and her voice had returned to normal A recheck by an otolaryngologist in another city four months following discharge from the sanatorium revealed the vocal cords to be entirely normal

COMMENT

Lieberman[1] of Philadelphia has this to say with relation to this condition Granuloma of the larynx following intratracheal anesthesia is probably occurring more frequently than the literature would indicate and perhaps more care should be taken A careful history is important Particular attention should be paid to a history of recurrent laryngitis and if this is elicited possibly intratracheal anesthesia should not be used The tube certainly should be passed under direct vision and with a minimum of trauma and only when the vocal cords are wide open The tube should be sterilized just before using The tube should be passed by a well trained anesthetist and great care should be taken to avoid undue movement of the tube during the operation

SUMMARY

A case of bilateral granuloma of the larynx is reported here The causation of this bilateral granuloma has been assumed to be due to the movement of the larynx over the endotracheal tube during too light a plane of anesthesia

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Announcement

THE AMERICAN ASSOCIATION FOR THORACIC SURGERY

Notice of Annual Meeting

The 34th annual meeting of the American Association for Thoracic Surgery will be held May 3, 4, and 5, 1954, in Montreal, Que, Canada Headquarters will be at the Sheraton Mount Royal Hotel

Requests for Hotel Reservations

These should be mailed *directly* to the Reservation Manager, Sheraton Mount Royal Hotel, Montreal, Que, Canada Please mention this Association, type of accommodation desired, date, and approximate hour of arrival If accommodations are desired elsewhere, please communicate directly with hotel of your choice

Thoracic Surgical Forum

After due consideration, the Council has decided to try an experiment by assigning one morning session to a "Thoracic Surgical Forum" for the presentation of short papers on current thoracic research, anatomy, modified surgical techniques, etc Papers at this *session will be limited sharply to ten minutes (including the showing of lantern slides or* other illustrative material) with three minutes as the maximum discussion of each paper

These papers will be published together in one issue of THE JOURNAL OF THORACIC SURGERY Maximum length 3,000 words without illustrations If illustrated, an appropriate number of words must be subtracted for each cut used

Abstracts for Papers

Abstracts for the presentation of papers at the 1954 meeting, including papers before the Forum, must be received on or before January 1, 1954, otherwise they will not be considered by the Program Committee

Abstracts should be labeled "For Forum" or "For Regular Program"

Five, repeat five, copies of each abstract should be sent to the Secretary of the Association, Dr Paul C Samson, 2938 McClure St, Oakland 9, Calif They should not be sent to the Editor

The abstracts should contain from 200 to 250 words and accurately reflect the contents of the completed paper

Applications for Membership

Applications for Associate Membership in the Association must be received by the Membership Committee not later than Jan 1 1954 to be considered for action in Montreal Applications received beyond this deadline will be deferred for consideration until 1955

Applicants must be sponsored by three Active or Senior Members of the Association In addition to the sponsoring statement on the application form the sponsors *must* submit a separate letter concerning the applicant direct to *Dr Lyman A Brewer III Chairman* of the Membership Committee 2010 Wilshire Blvd Los Angeles Calif Completed application forms should likewise be sent to Dr Brewer These regulations are at the direction of the Council and were made effective in 1952 at Dallas

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Original Communications

PHYSIOLOGIC CHANGES FOLLOWING OBSTRUCTION OF THE SUPERIOR VENA CAVA

Report of a Clinical Case and Experimental Studies

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IN THE course of dissecting the right pulmonary veins within the pericardium during a pneumonectomy for bronchiogenic carcinoma one of us (F. J. J.) was disturbed to find upon completion of the dissection that he had mistaken the intrapericardial pulmonary venous trunk (found as a frequent variation on the right) for the inferior pulmonary vein and had then inadvertently divided the superior vena cava. It was estimated that the superior vena cava had been obstructed for approximately fifteen minutes before the true state of affairs was recognized and it required forty-two minutes more to effect an anastomosis of the cava with the auricle. The azygos vein had been divided early in the course of the operation. Surprisingly enough the patient tolerated this physiologic insult quite well (death thirty hours later could be certainly attributed to respiratory functional inadequacy). We were unable to locate a report of a similar surgical misadventure although there are many reports of well-tolerated gradual superior vena cava obstruction resulting from inflammatory or neoplastic disease.

Carlson (1934) found that obstruction of the superior vena cava is well tolerated by the dog above the azygos vein. Recent experimental observations [illegible] Anderson and Watson (1952) demonstrated the ability of dogs to survive [illegible] of the superior and inferior venae cavae for ten minutes if the azygos [illegible]. However, Carlson's two dogs with obstruction below the azygos [illegible] minutes. Since these earlier observations were at such variance

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[illegible] University of Washington School of Medicine and [illegible] Annual Scientific Session of the Pacific Coast Surgical [illegible] with the behavior of our patient, studies were undertaken in the laboratory to clarify (1) the physiologic pressure changes resulting from acute occlusion of the superior vena cava and following its release, (2) the ability of the animal to survive permanent acute occlusion of the superior vena cava below the azygos vein, and (3) the role of the azygos vein in collateral return flow of venous blood to the heart.

CASE REPORT

R. H. P., a 59-year-old man, was admitted to the hospital, Jan. 27, 1953. Active pulmonary tuberculosis had been diagnosed in March, 1952, based on roentgenograms of the chest and the finding of tubercle bacilli in concentrate sputum smears. In 1918 orchidectomy had been performed for right tuberculous epididymitis, and in 1924 the left testis was removed for tuberculous disease. Right nephrectomy became necessary for tuberculous pyelonephritis in 1951, and similar involvement of the left kidney was suspected in March, 1952.

The patient was chronically ill, with physical evidence of marked pulmonary emphysema. Roentgenograms of the chest (available in series from October, 1948) revealed a fibrotic type of infiltration in the right apex which had increased moderately, especially in the upper third of the right lung, with some increased radiopacity in the hilar region. Routine laboratory studies were within normal limits. The blood sedimentation rate (corrected, Wintrobe) was 31 mm. per hour. Two acid-fast bacilli were found in the sputum on the week of admission, but cultures of the sputum for tubercle bacilli were reported positive. Pyelograms and urine studies failed to confirm the suspected tuberculosis in the remaining kidney. Bronchoscopy (June 4, 1952) revealed a partial obstruction of the right main bronchus by an irregular membranous structure which bled readily, and from which a biopsy was reported as showing squamous cell carcinoma. Studies of the pulmonary function revealed a maximum breathing capacity of 97 L. which was 72.5 per cent of the predicted maximum for this patient. Fifty-six per cent of the oxygen consumption was on the right, 52.5 per cent of the ventilation. In spite of this extremely poor pulmonary reserve, in view of the finding of carcinoma, pneumonectomy was advised and accepted by the patient and his family after full appraisal of the great risk entailed.

Operation.—With the patient in the face-down position, the right hemithorax was entered through the bed of the resected fifth rib. There were numerous firm adhesions about the apex of the upper lobe which contained extensive palpable lesions compatible with caseonodular and fibrous tuberculosis. Although large lymph nodes were felt about the hilus, the area was not fixed and it was apparent that we were dealing with a situation that was technically operable.

Complete adherence of the apex made it necessary to free the lobe by removing a portion of the thick parietal pleural peel in the endothoracic fascial plane. The mediastinal dissection was begun by exposing the innominate artery and vein and dividing the vagus nerve just beyond the recurrent laryngeal branch superiorly. The lymphatic structures, along with the phrenic and vagus nerves, were stripped from the lateral aspects of the trachea, esophagus, and aorta. The azygos vein was divided between ligatures and used as a tag to rotate the structures of the mediastinum outward. Two large paraesophageal nodes lateral to the mid-esophagus were removed separately from the main block of tissue and the esophagus was dissected free of its surrounding tissue throughout its entire length.

There were large, firm lymph nodes lying superior to the right main-stem bronchus between it and the superior vena cava, and the nodes at the tracheal bifurcation were also large and firm, but not adherent. These were suspected strongly of being involved with carcinoma but it was impossible to tell that their enlargement was not the residuum of the old tuberculosis. The bronchus was isolated, divided, and closed with interrupted sutures of 0000 silk.

The left main bronchus was then dissected down to the level of the left inferior pulmonary vein. The right inferior pulmonary ligament was incised at its base at a point approximately 2 cm. inferior to the right inferior pulmonary vein. Here the pericardium

of the right lung and there was extensive tuberculosis of the mediastinal lymph nodes The upper lobe was the site of extensive bronchiectasis with local ulceration of the bronchial mucosa and extensive chronic inflammatory changes throughout the upper lobe parenchyma

At necropsy the anastomosis of the superior vena cava was intact and patent Except for some excess of sanguinoserous fluid in the right hemithorax there was no demonstrable anatomic cause for death Clinically the patient showed signs and symptoms of progressive anoxia resulting from the respiratory insufficiency, consequent to a functional pulmonary reserve inadequate to sustain him through the early postoperative period

The period of acute superior vena cava obstruction in this patient lasted slightly less than one hour but was tolerated surprisingly well when viewed in the light of Carlson's experimental data The problem of temporary superior vena cava obstruction, with perhaps graft replacement, may become increasingly more frequent as radical intrathoracic procedures for carcinoma become more commonplace Experimental studies were made to determine some of the factors involved in acute temporary and permanent superior vena cava obstruction

EXPERIMENTAL DATA

Methods —Mongrel dogs weighing an average of 10 kilograms were used Two groups of experiments were carried out dogs with acute permanent superior vena caval obstruction, and dogs with acute temporary superior vena caval obstruction In the latter group pressure recordings were obtained from the proximal superior vena cava the right auricle, and the aorta before during, and immediately after the obstruction of superior caval blood flow A simultaneous electrocardiographic recording (Lead II) was obtained by using a four channel Sanborn Poly-Viso recording apparatus

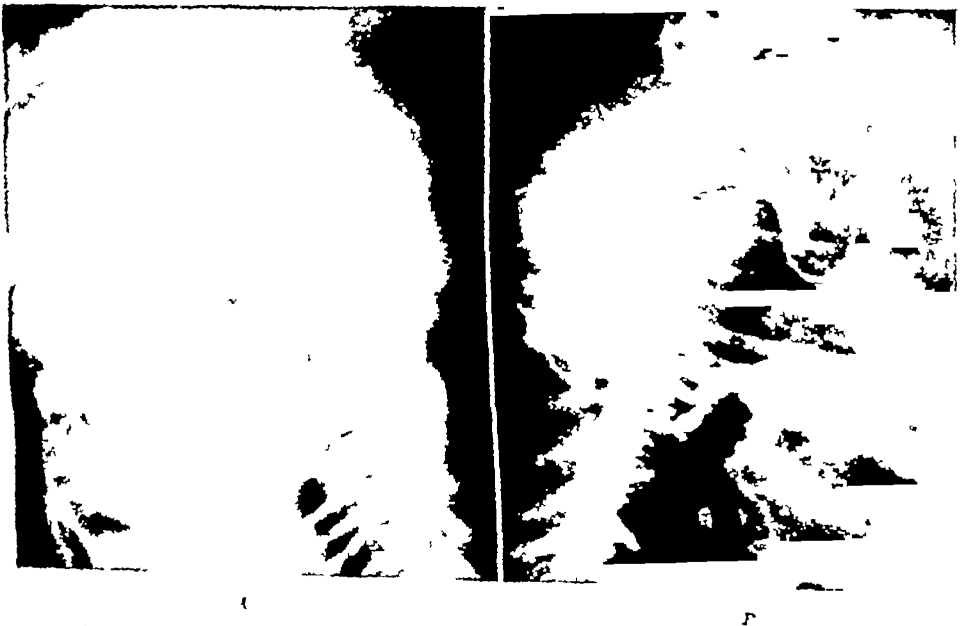
All operative procedures were performed under aseptic conditions and Nembutal anesthesia supplemented by positive pressure endotracheal ether oxygen The right pleural cavity was entered through the fourth intercostal space The superior vena cava was exposed from the azygos vein to the right auricle In six animals complete and permanent obstruction of the superior vena cava was obtained by application of two Potts coarctation clamps on the cava between the azygos vein and the right auricle, dividing the superior vena cava between these clamps and closing the cut ends by double rows of 00000 silk suture on an atraumatic needle

Temporary superior vena cava occlusion was produced in six dogs Pressure recordings were obtained in five animals The first animal had the superior vena cava obstructed for three hours and fifteen minutes, while the other five dogs had caval obstructions for two hours each An arbitrary occlusion period of two hours was thought to represent a maximum period which might be required to effect an anastomosis in the clinical case Pressure recordings were obtained by inserting polythene catheters (1 2 mm in diameter) into the proximal portion of the superior vena cava into the right auricle through the wall of the auricular appendage, and into the aorta either through the right subclavian or the femoral artery

Control recordings were obtained prior to clamping the vena cava Observations were recorded at the time the superior vena cava was obstructed by clamps at fifteen minute intervals for two hours, at the moment of release of the caval obstruction and for a short period thereafter

At the completion of the experiment the chest was closed in layers and the free air in the pleural cavity was aspirated as the lungs were re-expanded by positive endotracheal pressure Procaine penicillin (300,000 units) was given intramuscularly to each animal after the operation Postoperatively the animals were kept in cages in heated quarters and observed for survival time cyanosis and evidence of cerebral damage

One animal had a venogram done thirty-five days after division and closure of the superior vena cava proximal to the right auricle Fig 1 A illustrates the venogram from this animal made by injection of 20 c c of 70 per cent Diodrast through the polythene catheter inserted into the left external jugular vein A venogram immediately after superior vena caval obstruction was obtained in another animal (Fig 1 B) revealing a readily available collateral venous return from the head and forequarters of the dog



[illegible] thirty-five days after acute permanent obstruction of the [illegible] superior vena cava [illegible] the right auricle in the dog. B, Venogram [illegible] acute permanent obstruction of the superior vena cava [illegible] right auricle in the dog

As an initial exercise, temporary occlusion was effected for three hours and fifteen minutes in the first dog without recording pressure changes. Following the abrupt release of the clamp there was rapid distention of the auricle and the ventricles went into fibrillation from which they could not be extricated with the available electric defibrillator and death ensued.

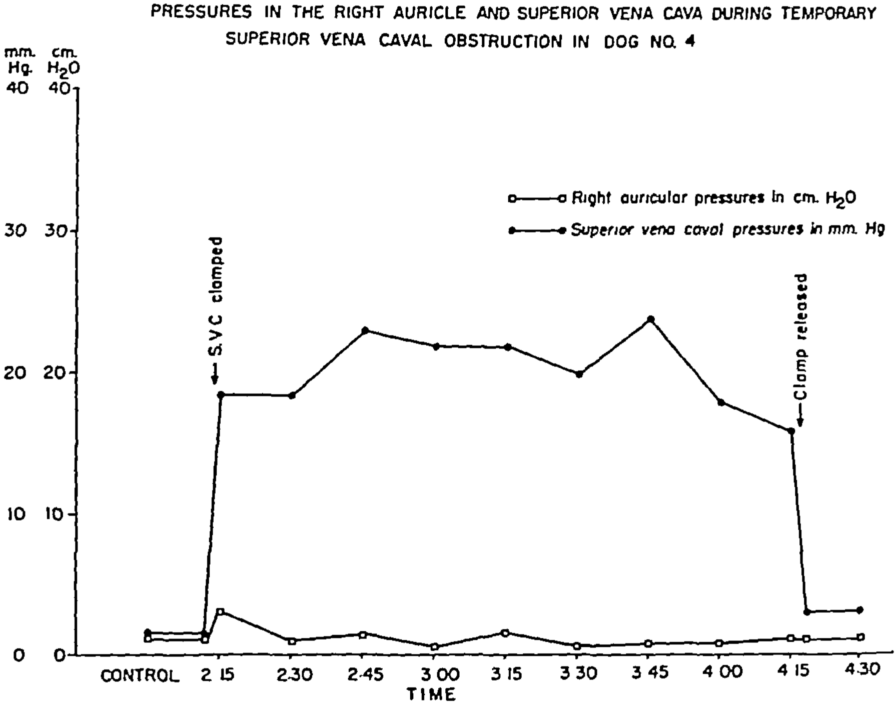
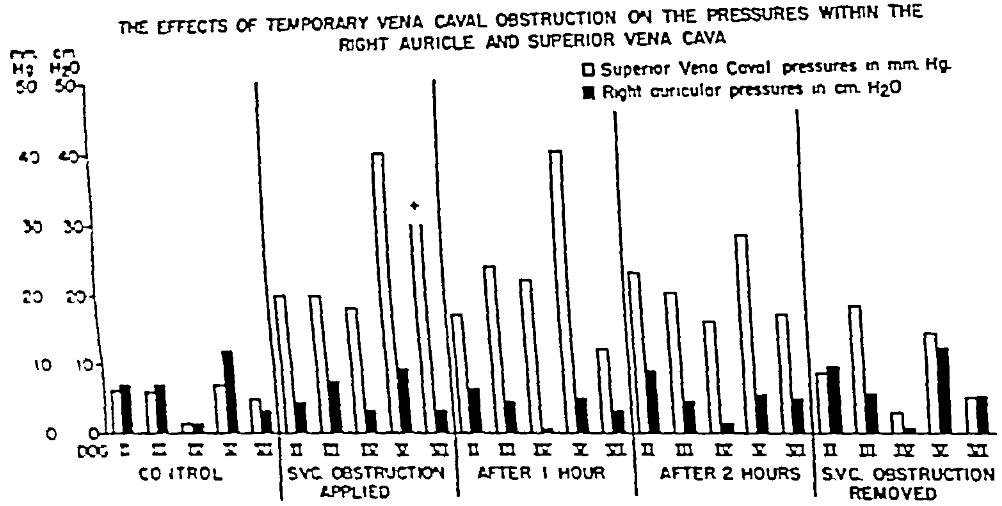


Fig 2.—A graph showing the auricular pressures (in centimeter of water) and the superior vena caval pressures (in millimeter of mercury) in the control period during caval occlusion and after release of the occlusive clamp in the dog.

Temporary obstruction for two hours was similarly carried out in five additional dogs. In all of these animals there was a prompt elevation of pressure in the superior vena cava proximal to the point of obstruction and relatively little change in the right auricular pressure. Fig 2 graphically illustrates the pressure alterations observed in Dog 4 after obstruction of the superior vena cava and immediately after its release. The electrocardiographic records did not reveal any significant arrythmia associated with superior caval obstruction or following its removal. This was contrary to our expectations in view of the reports by Carlson (1934) and the results obtained by us in the first animal in this series which died from ventricular fibrillation. Superior vena caval obstruction also did not produce significant alterations in the arterial blood pressure, an observation corroborating the findings of Andreasen and Watson (1952). Two dogs in this series died eighteen and eight hours, respectively, after operation from pulmonary atelectasis while the remaining two dogs were sacrificed while in good health one and six weeks, respectively, after temporary superior caval obstruction. All the animals in this group had the site of occlusion and proximal superior vena cava examined for thrombus formation but none was found.

Fig. 3 is a graphic representation of the superior vena caval obstruction in five dogs. Dogs 3 and 4 were sacrificed while in good health. Dogs 2 and 5 expired with pulmonary complications in the early postoperative period.

In all of these animals cyanosis of the mucous membranes and tongue was very marked during the period of superior caval obstruction. The three dogs which survived one week or more did not show a sustained intense cyanosis. The two survivors from among the dogs with acute permanent caval obstruction showed a decrease of the cyanosis several days after operation. The two dogs which died with pulmonary complications may well have had cerebral damage secondary to temporary venal obstruction. There was evidence of cerebral damage in four dogs whose venae cavae were permanently occluded. Three died without gaining consciousness. The fourth regained consciousness but displayed a flaccid paralysis of all extremities.



[illegible] illustration of the right auricular and superior vena caval pressures with [illegible] acute obstruction of the superior vena cava in five dogs.

DISCUSSION

Occlusion of the superior vena cava at the cava-auricular juncture produces a rapid rise in the intracaval pressure to plateau levels two to three and [illegible] times greater than the preocclusion level. Intense cyanosis occurs in the [illegible] and upper extremities as a result of the slowed venous return. [illegible] of the high plateau pressure may in the main be a re[illegible] [illegible] availability of the azygos system as an alternate route of [illegible] blood through the inferior vena cava is illustrated by [illegible] fifteen minutes following acute permanent pre atrial superior vena caval occlusion By comparison a similar venogram (Fig 1, *A*) shows only slight further dilatation of these venous collaterals thirty five days following the permanent caval occlusion Alterations in the peripheral vascular bed that may further reduce the volumes of blood returning from the upper extremities can only be hypothecated At any rate it would seem that the immediate availability of the azygos system to provide for collateral return of venous blood is an important factor in both limiting the height of the pressure rise proximal to the occlusion and possibly in permitting sufficient blood flow through the cerebral circulation to maintain cell viability for a considerable time in spite of intense cyanosis

Similar experiments with the azygos vein tied and with the azygos intact but occluding the superior vena cava above it would be interesting Andreasen and Watson (1952) clearly indicate the importance of the azygos vein when complete temporary obstruction of venous return to the heart is produced We recognize certain fallacies in the comparison of the venous circulation in the extremities of the experimental animal to the human being, but feel that the caval and azygos systems, devoid of valves in both, should be similar

The drop in intra-auricular pressure is much less dramatic than might at first be expected Since in the dog 60 per cent of the venous return to the heart is through the inferior vena cava, the volume of blood available for auricular filling is still great even after superior caval occlusion To this is added the sizable contribution of the azygos collateral blood flow The resultant diminution in venous return is reflected in reduced cardiac output which is not sufficiently reduced markedly to lower the intra-aortic pressure Temporary occlusion for two hours, though a serious physiologic shock, is tolerated by the dog surprisingly well These observations bear out the results of Gerbode (1950), who found that occlusion of the superior vena cava was tolerated for twenty-five minutes in making experimental anastomoses between the superior vena cava and the left auricular appendage in dogs The findings in our experiments would seem to bear out the impression from the single clinical case that patients might tolerate occlusion of the superior vena cava long enough to permit reconstructive anastomosis or even replacement by graft The increasing frequency of major thoracic procedures with dissection of vessels about the pulmonary hilum within the pericardium, as described by Allison (1946) or of so-called "radical pneumonectomy," described by Cahan and his associates (1951), may increase the frequency of caval injury and the necessity for its reconstruction

Permanent occlusion of the superior vena cava at this level presents a much more serious physiologic shock to the animal It is, however not universally fatal, two of the six animals survived Those that died exhibited evidences of cerebral damage consequent to the selective cyanosis produced by the procedure

Bailey (1952) has recently described the development of ventricular fibrillation following the release of simultaneously occluded superior and inferior venae cavae We had observed a similar occurrence in the first experiment following occlusion of the superior vena cava for over three hours and felt that ventricular fibrillation might be produced by this means fairly readily In this our expectations were unfulfilled since no subsequent disturbances in cardiac mechanism occurred in any of the experimental animals following caval occlusion for two hours It may require longer caval occlusion to produce ventricular fibrillation with any degree of certainty

SUMMARY

A clinical case in which the superior vena cava was divided and re-implanted into the right auricle prompted experiments with occlusion of the cava to evaluate the resultant physiologic changes Temporary occlusion at the cava-auricular junction of two hours duration was tolerated by the experimental animal The superior caval pressure rose rapidly to maintain a high plateau level two to three and one half times greater than the preocclusion level The azygos system provided an immediate route for collateral shunt around the occlusion Pressures within the right auricle and the aorta fell only slightly Permanent occlusion at this level with an intact azygos system, was tolerated by two of the six dogs

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INCLUSION DISEASE OF INFANCY

CASE REPORT

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CYTOMEGALIC inclusion disease (also referred to as generalized salivary gland virus infection) is a systemic disease, characterized by the presence of intranuclear and intracytoplasmic inclusion bodies in gigantically enlarged cells of many organs While predominantly an affection of infants and new borns, cases in older children and adults have been reported Inclusion bearing cells of similar morphology have been found in the ducts of salivary glands of 12 per cent of infants in a consecutive autopsy series,[1] probably representing latent infection or a commensal type of relationship Although the so called "salivary gland virus" is more or less universally accepted as the etiological agent, no report of its recovery or cultivation from clinical material has appeared to the present time

A recent comprehensive review of the literature by Smith and Vellios[2] yielded sixty-nine cases, to which were added twenty new ones All of these were discovered at autopsy Many were associated with other diseases or debilitating conditions, which latter, rather than inclusion disease itself, seemed to be the proximate causes of death A few occurred as isolated infections without recognized accompanying disease

Until very recently no satisfactory diagnostic measures have been available, and for this reason figures as to incidence and mortality must be considered open to question Fetterman[3] has recently described finding typical inclusion-containing cells in the urine sediment of an infant who subsequently died of inclusion disease the disease was demonstrated at autopsy While the application of this discovery may well lead to more frequent recognition, there has been to this time no description of a case in which the diagnosis has been established during the patient's life, and in which there has been clinical recovery The present case is therefore, unique in this respect and also in the concomitance of cystic lung disease, for which the preceding inclusion disease may reasonably be held responsible

CASE REPORT

The patient, D B , a white boy, was the first born of twins, delivered on Oct 26, 1951 He weighed 2,300 grams, cried spontaneously, and exhibited normal vigor at birth About the sixth day of life, his appetite began to wane He was moderately jaundiced, the spleen extended 3 cm below the costal margin and the liver was barely palpable No other positive physical signs were found

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From Germantown Dispensary and Hospital
Received for publication April 27 1953

On the following day, cyanosis appeared during bouts of crying, and the cry was weak and high pitched. The rectal temperature was elevated to 100° F for a few days, then fell to normal. Cyanosis and dyspnea became progressively worse. About a week after the onset of symptoms, a chest x ray film showed "a marked opacity over the upper half of the right lung, which represents either consolidation or atelectasis or both." (Fig 1.) The first chest signs made their appearance on November 19, described by the observer as "decreased breath sounds over the right upper lobe area." By this time the baby had become ominously dyspneic and cyanotic despite continuous oxygen administration. A loose cough, productive of small quantities of blood tinged mucus, appeared, coarse rales became audible at the right base, and no normal alveolar breath sounds could be heard on the right side. The radiologic density had, by November 24, spread to involve the entire right lung field. The trachea and mediastinum were displaced to the right, and a small sharply marginated area of radiolucency had appeared in the upper portion of the lower lobe.

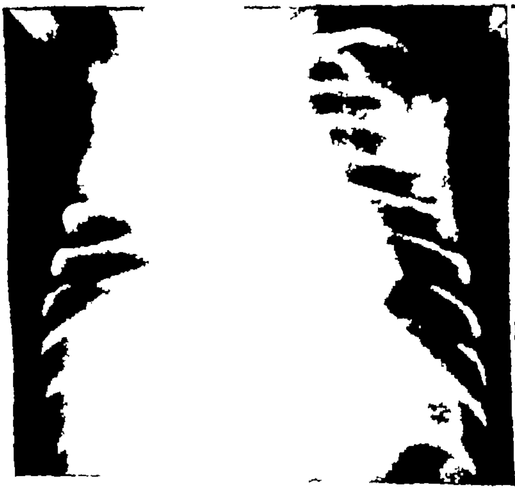

Fig 1

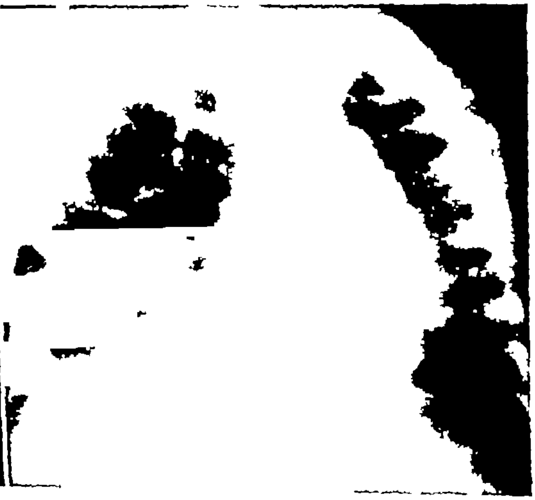

Fig 2

From this point onward there was gradual improvement in the baby's general condition. The cough, dyspnea and cyanosis subsided partially, but did not disappear. His appetite became slowly greater, and he began to gain weight in spite of obvious respiratory difficulty. Serial x ray studies disclosed the development of four air filled cysts at the site of the previously observed radiolucent area. These appeared to compress the [illegible] and displaced the mediastinum slightly to the left (Fig 2).

The laboratory work done during the first two months of life revealed no specific pattern. The hemoglobin was 17.5 Gm /100 ml at birth, gradually declined to 9.6 Gm /100 ml. The white blood cell count varied moderately but was never significantly elevated and the [illegible] was always within normal newborn limits. Only banal organisms were [illegible] and pharyngeal swabs. Blood cultures taken on several occasions [illegible] remained [illegible] rile for six weeks.

[illegible] second [illegible] of the pulmonary cysts and because of continued [illegible] Thoracotomy was performed December 19 [illegible] the lower portion of the upper lobe and the apex of the lower lobe [illegible] filled most of the right hemithorax [illegible] against the medi[illegible] with little difficulty. The [illegible] and the need for oxygen during ished promptly. In later radiographs a small residual cystic area in the right cardiophrenic angle was visible. This has shown no enlargement since and does not seem to cause discomfort. The patient was discharged on March 5, 1952, in good condition. Since discharge, he has remained entirely well and is developing normally.

Microscopic Appearance.—The excised portions of lung showed moderate increase in interstitial tissue, with occasional areas of striking fibrosis in interalveolar septa and peribronchial tissues. A rather sparse infiltration of lymphocytes, plasma cells, and histiocytes was widespread in distribution. The cysts were lined by delicate layers of fibrin, with surrounding thin laminas of young connective tissue. In several of the sections, communication of cysts with small bronchi could be definitely established.

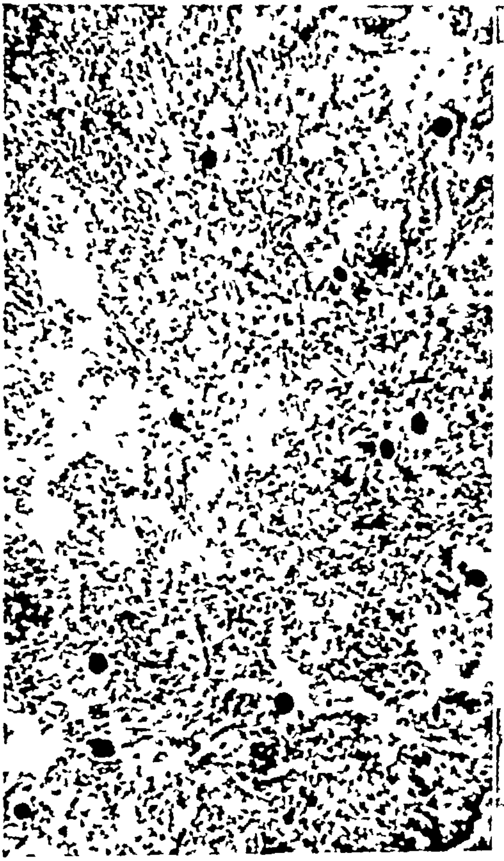

Fig 3

Fig 4

Scattered throughout all regions of the lung tissue were large cells, 17 to 24 microns in diameter, containing both intranuclear and intracytoplasmic inclusion bodies (Fig 3). These cells lay largely within the lumina of terminal bronchioles and were apparently derived from bronchiolar lining cells. The intracytoplasmic inclusions consisted of crescent-shaped groups of faintly basophilic granules lying at the periphery of the gigantic cells. Within each nucleus was a large spherical, homogeneous reddish purple inclusion 7 to 8 microns in diameter, almost filling the entire structure. A narrow clear space lay between the border of the inclusion and the peripherally clumped nuclear chromatin in about one half of the cells. In the remainder the clear space was obliterated, the margins of the inclusions being indistinct

(Fig. 4) This phenomenon has been regarded as representing degeneration of the virus and regression of disease a concept which coincides with the clinical status of this case at the time the lung was resected

In one tissue block was found projecting into a small bronchus a nodule, composed of moderately dense richly vascular, fibrous stroma, imbedded in which were myriad giant inclusion bearing cells Bronchial mucosa covered the base of the polypoid structure, but was absent over its crest (Fig 5) Practically all of the intranuclear inclusions in the nodule had indistinct margins as previously described The size, location, and structure of the lesion implied that it had obstructed the bronchiole it occupied at least partially, and possibly had had a ball valve effect

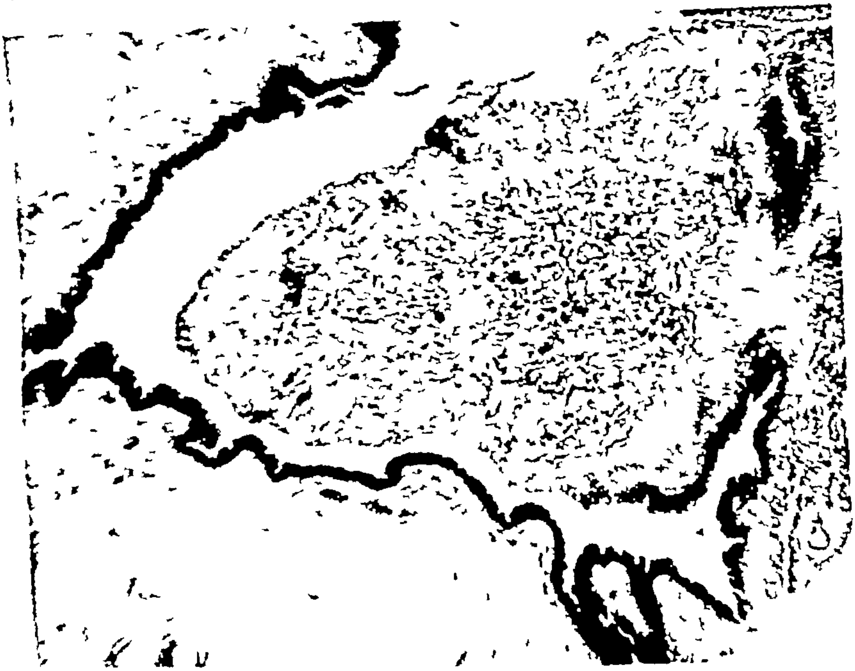

FIG 5

DISCUSSION

This case reveals certain facets of the nature of cytomegalic inclusion disease previously suspected but not clinically demonstrated Two points deserve special comment The first of these is the simple fact that the patient recovered Although no previous reported case has been proved prior to autopsy this probably is more the result of lack of diagnostic measures and the tendency of the disease to be coexistent with serious conditions than an [illegible] of it as a universally fatal infection Nonfatal cases almost certainly occur perhaps with greater frequency than more serious forms The [illegible] such studies as suggested by Fetterman may lead to more frequent [illegible] of milder instances of the disease and their segregation from [illegible] vague category "virus infection

The other noteworthy point in the present case is that there appeared [illegible] with strong indication that this was the result of the pre ceding virus infection Such relationship is also suggested in Cases 11 to 15 of Smith and Vellios, all of whom had fibrocystic disease of the pancreas associated with cytomegalic inclusion disease Whether these entities, and other similar disorders of late childhood and adult life may frequently be the sequelae of salivary gland virus infection can only be proved or disproved by the accumulation and study of an adequate series of healed cases of inclusion disease

*It is believed that, in the child described here, the illness began as a pri*mary infection with the salivary gland virus, acquired either in utero, or more likely *in the* immediate postnatal period Prematurity may well have been a predisposing factor Bronchial and bronchiolar swelling, with or without the formation of intrabronchial polypoid granulomata, is credited as having been the direct cause of the pulmonary cysts which later developed Changes in interalveolar supportive tissue were probably contributory Regression of the acute phase of the disease, either spontaneously or under the influence of antibiotics, began about four weeks after the onset of symptoms At the time of lobectomy, the disease was in its terminal phase Had a greater period of time elapsed before operation, it is entirely possible that all evidences of the foregoing inclusion disease would have vanished, leaving only a cystic lung of cryptic etiology

SUMMARY

A case is described in which a newborn infant developed pulmonary cysts following an episode of pneumonitis shortly after birth The excised portions of lung showed the histologic picture of cytomegalic inclusion disease The patient recovered without incident This is believed to be the first reported case of cytomegalic inclusion disease in which recovery has occurred It is also significant that in this case structural lung changes were apparently the result of salivary gland virus infection

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BRONCHIOGENIC CARCINOMA

A STATISTICAL REVIEW OF TWO HUNDRED AND THIRTY-FOUR AUTOPSIES

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HINES, ILL.

OBJECTIVE

A GROUP of 234 consecutive autopsies on cases of bronchiogenic carcinoma are reviewed in this paper to determine the different clinical types and the most common sites of metastases. The literature is also reviewed.

DEFINITION

It is the widely accepted conviction that all primary pulmonary malignancies of epithelial origin arise from the bronchi or their accessory glands. Such malignancies are therefore termed bronchiogenic carcinoma. 1550

HISTORY

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Johannes Agricola, in the sixteenth century, first described the symptoms of bronchiogenic carcinoma. The pathology of pulmonary tumors was first described in 1766 by Morgagni who also gave a full autopsy report in which it is possible to recognize the present day descriptions of lung carcinoma.

Bayle, in 1810, reported three cases of primary cancer of the lung and noted diffuse and nodular types.

Laennec and his co-workers in 1819 described "encephaloid" of the lung but they were not able to diagnose it ante mortem. Stokes in London in 1837 stated that frequent and severe attacks of bronchitis, resisting the usual methods of treatment, is suspicious of lung malignancy. He also gave an account of the physical signs, the qualities of the sputum, and the differential diagnosis between these signs and those of aneurysm. In 1843, Walsche termed this condition cancer. In the same year Kohler, of Germany, wrote a monograph on the subject. In 1842 Stokes made the first diagnosis by physical examination and gave a complete description of its clinical manifestations. Virchow in 1863 first described the pathologic process of pulmonary tumors including cancer of the lung. It was his opinion that primary cancer of the lung was [illegible]

[illegible] in 1896 found 37 collected cases while Adler in 1911, in a study of primary bronchiogenic carcinoma, found 360 cases reported in the literature. [illegible] concluded the failure to recognize lung cancer had given rise to the [illegible] impression that it was a rare malignancy.

[illegible] Chest and Thoracic Surgery, Hines Veterans Hospital [illegible] Veterans Administration [illegible] published with the approval of the Chief [illegible] the authors are not [illegible] result of [illegible] policy of the Veterans Administration.

[illegible]

HISTOPATHOLOGY

The exact origin or cell derivation of each particular type of bronchiogenic carcinoma is not entirely settled, but suffice it to say we believe that the epidermoid and undifferentiated carcinomas arise from the basal cell layer and the adenocarcinomas arise from the bronchial glands

We attempted to simplify our classification by using three main categories each with its individual subdivisions We included in the epidermoid group the squamous cell carcinoma with and without pearl formation and the undifferentiated squamous-cell type These are made up of large eosinophilic staining cells, appearing polyhedral and platelike with a relatively small nucleus rich in chromatin The adenocarcinomas included mucus- and nonmucus producing types The undifferentiated group, which we feel is the most malignant, includes the so called "oat-cell," round-cell and small cell carcinomas Microscopically, it is a small ovoid cell with a large nucleus, rich in chromatin, and appearing like a lymphocyte in fixed hematoxylin and eosin material These cells closely resemble lymphosarcoma cells We feel that any further differentiation is a matter of personal impression and interpretation These various groups occasionally occur in combination with one cell type predominating

We found no cases that would satisfactorily meet any or all of the criteria established for the diagnosis of the so-called alveolar-cell carcinoma We were able to find a primary in the main stem bronchus with dropped metastases in the alveoli in several cases which gave the impression of a so called alveolar cell carcinoma In more recent literature the so-called alveolar-cell carcinoma has been termed adenomatosis and is felt not to be in the carcinoma realm

SITES OF METASTASES

The problem of metastases from malignant pulmonary tumors is of major importance since the employment of lobectomy and pneumonectomy in its treatment The routes of spread are not many, but these must be considered (1) lymphogenous spread, (2) hematogenous spread, including the vertebral veins, (3) direct extension, (4) implantation, following such procedures as aspiration, aspiration biopsy, and operation, and (5) bronchiogenic spread

It is believed that the frequent occurrence of metastasis in carcinoma of the lung is due to the fact that the lungs have such a rich vascular and lymphatic bed There is a greater tendency for bronchiogenic carcinoma to be disseminated throughout the body by the invasion of blood vessels than carcinomas arising elsewhere

Carcinomas arising elsewhere liberate emboli into systemic veins which are caught or filtered out in the lung, while those liberated in the portal venous system find their way into the liver Those liberated from the lungs into the pulmonary veins, or into the left chamber of the heart, will be caught in any peripheral organ to which they are carried

The usual tendency is to invade regional lymphatics thus the parabronchial and peritracheal nodes first then the mediastinal lymph nodes Early metasta

TABLE I. HISTOLOGIC TYPES

	HINES 1942 1947		KOLETSKY[1] 1936		ARKIN AND WAGNER[2] 1936		TENZEL[3] 1936	
Total No of cases	234		125		74		192	
Epidermoid	145	61 96%	58	46 4%	21	28%	105	54.58%
Adenocarcinoma	21	8 97%	33	26 4%	18	24%	50	25 04%
Undifferentiated	68	29 06%	34	27 2%	31	43%	37	19 27%

sis is the rule in primary bronchiogenic carcinoma Signs of metastases may be the presenting symptom or symptoms of the patient and may appear early

Our series showed 61 69 per cent epidermoid carcinoma, 8 97 per cent adenocarcinoma, and 29 06 per cent undifferentiated This demonstrated that 6 out of 10 were epidermoid carcinoma 3 out of 10 were undifferentiated and 1 out of 10 was an adenocarcinoma

TABLE II SITE OF ORIGIN

		HINES 1942 1947		KOLETSKY[1] 1936			HINES 1942 1947		KOLETSKY[1] 1936	
Right side	Total No	138		81		Left side	96		44	
	Epidermoid	86	62 31%	37	45 68%		58	61 41%	21	47 73%
	Adenocarcinoma	12	8 69%	22	27 16%		10	10 41%	11	25 00%
	Undifferentiated	40	28 98%	22	27 16%		28	28 11%	12	27 27%

We found the right side more frequently involved than the left (58 9 per cent originated on the right side which was a little over one-half) This may in all probability be due to the fact that the right main stem bronchus is an almost direct continuation of the trachea

The epidermoid variety originated most frequently on the right side the undifferentiated group was practically equally divided with the right side still somewhat more predominant while the adenocarcinoma group were equally divided

TABLE III COMPARATIVE SERIES OF INDIVIDUAL SIDES

	HINES	OCHSNER AND DEBAKEY[4]	FISCHER[5]	ARKIN AND WAGNER[2]	KOLETSKY[1]
Total No of cases	274	4732 (Collected)	3775	135	125
Right side	58 97%	58 4%	53%	60%	64 8%
Left side	41 03%	41 6%	45%	40%	35 2%
Bilateral			2%		

Ochsner and DeBakey in 1941 reported a series of 4 732 in which 58 4 per cent were on the right side and 41 6 per cent were on the left Fischer in 1930 reported 3 775 collected cases in which there were 53 per cent on the right side 45 per cent on the left side and 2 per cent were bilateral Arkin and Wagner in 1936 reviewed 135 cases of which 60 per cent originated on the right side and 40 per cent on the left side Koletsky in 1936 had 125 cases of which 64 8 per cent were on the right side and 35 2 per cent originated on the left side Our series showed 58 97 per cent on the right side with 41 0 [illegible]

TABLE IV LYMPH NODE METASTASES

			EPIDERMOID			ADENOCARCINOMA			UNDIFFERENTIATED		
	NO	% OF TOTAL	NO	% OF MET	% OF EPID	NO	% OF MET	% OF ADENO	NO	% OF MET	% OF UNDIFF
Peribronchial	126	53.85	70	55.56	48.28	12	9.52	57.14	44	34.91	64.71
Mediastinal (including peritracheal)	98	41.88	54	55.10	37.24	10	10.20	47.62	34	34.69	50.00
Abdominal (including retroperitoneal)	42	17.95	23	54.76	15.86	3	7.14	14.29	16	38.09	22.06
Cervical	18	7.69	13	72.22	8.97	2	11.11	9.52	3	16.67	4.41

Lymph nodes showed the greatest involvement in our series. There were 126 of the 234 cases which showed peribronchial lymph node metastases. This was 53.85 per cent of the total number of cases. Of this 126, 70 (55.56 per cent) of the total were epidermoid carcinoma, while 48.28 per cent of the total number of epidermoid cases demonstrated peribronchial involvement. We also found that 12 (9.52 per cent) cases were adenocarcinoma, constituting 57.14 per cent of the total number of the adenocarcinomata. The undifferentiated category was made up of 44 (34.91 per cent) cases showing peribronchial metastases but this constituted 64.71 per cent of this cell type.

Mediastinal including peritracheal glands were involved in 98 cases, 41.88 per cent of the total number. Of these 54 (55.10 per cent) were epidermoid, this being 37.24 per cent of this particular category, 10 (10.20 per cent) were adenocarcinomas constituting 47.62 per cent of the total number of adenocarcinomas. Thirty-four (34.69 per cent) of the undifferentiated group showed involvement, this making up 50 per cent of the total number of the undifferentiated cell type.

Forty-two cases (17.95 per cent) in our series demonstrated abdominal and retroperitoneal lymph node involvement.

Metastases to cervical lymph nodes occurred in 18 cases. No involvement of axillary lymph nodes was demonstrated.

TABLE V METASTASES TO THE LIVER

HINES 1942-1947	TOTAL NO	% OF TOTAL	% OF CELL TYPE	SAMPSON[2] 1935		TENZEL[3]		KOLETSKY[1] % OF CELL TYPE
	90	38.46		35	% OF CELL TYPE	74	% OF CELL TYPE	
Epidermoid	48	53.33	33.10	4	11.42	29	28	18
Adenocarcinoma	9	10.00	42.86	20	57.14	27	54	50
Undifferentiated	33	36.67	48.53	11	31.43	18	49	66

Hepatic metastases were found as frequently as some of the other more commonly expected sites. We had a total of 90 (38.46 per cent) in which liver metastases were present, 48 cases (53.33 per cent of the total) or 33.10 per cent of the epidermoid class. Nine cases of adenocarcinomata (10 per cent of the total) or 42.86 per cent of this cell type and the undifferentiated group comprised 33 cases (33.67 per cent of the total) while this was 48.53 per cent of the cell type.

Sampson in 1935 reported 35 cases with metastases to the liver He broke this number down showing 4 cases of epidermoid which was 11.42 per cent while 20 cases or 57.14 per cent were adenocarcinomas and the undifferentiated group constituted 11 cases or 31.43 per cent

Tenzel reported 74 cases in which he reported 29 epidermoid 27 adenocarcinoma and 18 as undifferentiated carcinomas 49 per cent of this cell type

Koletsky in 1936 reported 125 cases 18 per cent epidermoids 50 per cent adenocarcinoma and 66 per cent in the undifferentiated group showed hepatic metastases

TABLE VI ADRENAL METASTASES

	HINES			TENZEL[3]		SAMPSON[2]		KOLETSKY[1]
	TOTAL NO 69	% OF TOTAL 38.03	% OF CELL TYPE	59	% OF CELL TYPE	21	% OF TOTAL	% OF CELL TYPE
Epidermoid	30	36.18	34.48	21	20	3	14.29	54.0
Adenocarcinoma	11	12.76	52.38	22	44	16	76.19	12.0
Undifferentiated	28	31.45	41.18	16	45	2	9.52	64.0

CASES	OCHSNER AND DEBAKEY[4]	MILLER AND JONES	AIKIN AND WAGNER[2]	MATTICK AND BURKE	GRAHAM[7]	HINES
140	17.6%	9 %	4 %	8%	33.3%	38.03%

Almost 2 out of every 5 bronchiogenic carcinomata have adrenal involvement This may be the chief reason that some of the people whom we see in an advanced state appear so debilitated Of this group 1 out of 3 is epidermoid cell 1 out of 8 is adenocarcinoma and 1 out of 3 undifferentiated

TABLE VII KIDNEY METASTASES

	HINES			SAMPSON[2]		TENZEL[3]		KOLETSKY[1]
	TOTAL NO	% OF TOTAL	% OF CELL TYPE	TOTAL NO	% OF TOTAL	TOTAL NO	% OF CELL TYPE	% OF CELL TYPE
	68	28.21		[illegible]		35		
[illegible]	8	57.58	26.21	2	9.69	14	13	15
[illegible]	9	[illegible]	42.85	17	73.91	14	28	26
[illegible]	19	28.78	26.47	4	17.39	7	19	20

	HINES	OCHSNER AND DEBAKEY[4]	WILLIS AND HAMLIN	AIKIN AND WAGNER[2]	MILLER AND JONES[4]
[illegible]	231	279	44	74	808
[illegible]	60	412	11	29	122
[illegible]	28.21	16	25	40	15.9

We found 28 per cent involvement of the kidney suggesting that almost 1 [illegible] renal metastases The epidermoid carcinoma metastasized to [illegible] 1 out of 4 cases the adenocarcinomas in about 1 out of 7 and [illegible] group in about the same proportions as the epidermoids [illegible] 23 cases of which 2 or 9.69 per cent were epider[illegible] 17 or 73.91 per cent were adenocarcinoma and 4 cases of [illegible] undifferentiated group

TABLE VIII BONE METASTASES

	HINES			SAMPSON[5]		KOLETSKY[1]
	TOTAL NO	% OF METAS	% OF CELL TYPE	TOTAL NO	% OF METAS	% OF CELL TYPE
	41	17 52		30		
Epidermoid	26	63 41	17 93	8	26 67	10
Adenocarcinoma	6	14 63	28 57	17	56 67	32
Undifferentiated	9	21 95	13 24	5	16 66	23

	HINES	OCHSNER AND DE BAKEY[4]	ARKIN AND WAGNER[2]	MILLER AND JONES[4]
Total no of cases	234	2 579	74	808
No of cases showing metastases	41	527	21	88
% of metastases	17 52	20 4	28	10 1

Tenzel in 1936 had 35 cases in which he reported renal involvement, 14 epidermoid carcinoma, 14 adenocarcinoma and 7 in the undifferentiated group

Koletsky in 1936 reported 15 per cent epidermoid carcinoma 36 per cent adenocarcinoma and the undifferentiated group, constituting 20 per cent

Bony metastases are not being reported as individual osseous sites but are grouped together in a single total

TABLE IX LUNG METASTASES

	HINES			TENZEL[3]		KOLETSKY[1]
	TOTAL NO	% OF METAS	% OF CELL TYPE	TOTAL NO	% OF CELL TYPE	% OF CELL TYPE
	34	14 57		52		
Epidermoid	21	61 47	14 48	20	19	12
Adenocarcinoma	5	14 71	23 81	23	46	55
Undifferentiated	8	23 52	11 77	9	24	11

	HINES	MILLER AND JONES[4]	ARKIN AND WAGNER[2]	SAMPSON[5]
Total no of cases	234	808	74	40
Total no showing metastases	34	173	24	10
Per cent of total	14 57	21	32	25

TABLE X METASTASES TO HEART, PERICARDIUM, AND MAJOR VESSELS

	HINES			TENZEL[3]			SAMPSON[5]		KOLETSKY[1]
	TOTAL NO	% OF TOTAL	% OF CELL TYPE	TOTAL NO	% OF TOTAL	% OF CELL TYPE	TOTAL NO	% OF TOTAL	% OF CELL TYPE
	26	11 11		14	7 29		25		
Epidermoid	18	69 23	12 41	8	57 14	8	11	44	2 5
Adenocarcinoma	0	0 00	0 00	4	28 57	8	6	24	23 0
Undifferentiated	8	30 77	11 76	2	14 28	5	8	32	5 7

	HINES	OCHSNER AND DE BAKEY[4]	MULLIGAN AND HARPER[8]	ARKIN AND WAGNER[2]	MATTICK AND BURKE[6]
Total no of cases	234	2,579	44	74	808
No of cases with metastases	26	268	5	10	22
Per cent of total	11 11	10 4	11 6	14	2 7

There is no predilection for any particular bony structure. We found almost every bone in the body involved except the hands and feet. There was 1 out of every 6 cases which showed bony metastases with the epidermoid group predominating, the undifferentiated group was second, and the adenocarcinoma last.

The lung was involved by metastases in 1 out of every 7 cases with the epidermoid group still predominant. The undifferentiated group was second in number while the adenocarcinoma still made up the smallest group.

Mediastinal structures were involved in 11 per cent of our cases, the epidermoid carcinoma predominated with the undifferentiated group being second. We found no cases of adenocarcinoma.

TABLE XI. METASTASES TO THE PLEURA

	RINES			TENZEL[3]		SAMPSON[4]	
	TOTAL NO.	% OF TOTAL	% OF CELL TYPE	TOTAL NO.	% OF CELL TYPE	TOTAL NO.	% OF TOTAL
	26	11.11		4[illegible]		45	
Epidermoid	15	57.6[illegible]	10.[illegible]4	18	17	15	[illegible]
Adenocarcinoma	[illegible]	11.54	14.29	16	[illegible]2	18	40.00
Undifferentiated	[illegible]	[illegible]0.77	11.7[illegible]	9	24	12	26.67

	RINES	MILLER AND JONES[4]	MULLIGAN AND HARPER[5]	MEKIN AND WAGNER[2]
Total no. of cases	274	808	44	74
No. of cases with metastases	26	28[illegible]	14	[illegible]
% of total with metastases	11.11	[illegible]	[illegible]1.82	45

The pleura was involved in 11 per cent with the epidermoid variety predominant.

TABLE XII. BONE METASTASES

	RINES			TENZEL		POLITSKY[2]		SAMPSON	
	TOTAL	% OF TOTAL	% OF CELL TYPE	TOTAL NO.	% OF CELL TYPE (% total)	TOTAL NO.	% OF CELL TYPE	TOTAL NO.	% OF TOTAL
	19	8.11		[illegible]	11.08	10		15	
Epidermoid	11	[illegible]	7.[illegible]	[illegible]	[illegible]	1	[illegible]	2	13.[illegible]
Adenocarcinoma	[illegible]	1[illegible]	14.29	1[illegible]	[illegible]	5	[illegible]0	12	80.00
Undifferentiated	5	[illegible]1	[illegible]	[illegible]	[illegible]	4	[illegible]0	1	[illegible].67

	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]4	[illegible]	[illegible]	[illegible]4	[illegible]
[illegible]	1[illegible]	[illegible]	[illegible]	18	1[illegible]
[illegible]	[illegible]1	14[illegible]	[illegible]	24	10.5[illegible]

[illegible] our hospital [illegible] shown that the vertebral veins [illegible] metastases to the brain and central nervous sys[illegible]

[illegible] tumor to [illegible]

where in the body. Central nervous system metastasis may come from a tumor in almost any organ of the body, but the lung is the most frequent site of such a malignancy.

The first clinical manifestations of bronchiogenic carcinoma may be due to intracranial metastases, simulating a symptom complex produced by a rapidly growing and highly invasive primary tumor of the brain. King and Ford after reviewing 100 cases at Johns Hopkins concluded that carcinoma of the lung metastasizes to the brain more frequently than any other type of malignancy. This is due to the malignant cells being carried by the blood stream to the brain without passing through the capillary bed of the lungs. They reported that of 448 cases 52, or 12 per cent, showed symptoms referable to the central nervous system rather than the bronchus. There were 19 cases or 4 per cent in which the symptoms referable to the central nervous system were the presenting ones. The type of carcinoma was not a factor in the incidence of metastasis to the central nervous system.

There were 19 cases (8.11 per cent) of demonstrable brain metastases in our series. This indicated 1 out of every 12 had such involvement. In some clinics as high as 1 out of 5 has shown brain involvement. Here again the epidermoid class predominated, while the undifferentiated group was second, and the adenocarcinoma third.

TABLE XIII. MISCELLANEOUS

	TOTAL NO.	% OF TOTAL	EPIDERMOID			ADENOCARCINOMA			UNDIFFERENTIATED		
			TOTAL NO.	% OF TOTAL	% OF CELL TYPE	TOTAL NO.	% OF TOTAL	% OF CELL TYPE	TOTAL NO.	% OF TOTAL	% OF CELL TYPE
Pancreas	17	7.26	5	29.41	3.45	0	0.00	0.00	12	70.59	17.78
Spleen	14	5.55	7	50.00	4.82	1	7.14	4.76	6	42.86	8.82
Skin	8	3.41	6	75.00	4.14	0	0.00	0.00	2	25.00	2.84
Bowels (large and small)	5	2.13	2	40.00	1.38	0	0.00	0.00	3	60.00	4.41
Prostate	3	1.28	1	33.33	0.69	0	0.00	0.00	2	66.67	2.94
Diaphragm	2	0.85	1	50.00	0.69	0	0.00	0.00	1	50.00	1.47
Thyroid	2	0.85	1	50.00	0.69	0	0.00	0.00	1	50.00	1.47
Testicle	1	0.43	0	0.00	0.00	0	0.00	0.00	1	100	1.47
Gall bladder	1	0.43	1	100	0.69	0	0.00	0.00	0	0.00	0.00

This table includes other organs of the body in which metastases were found. We had 17 cases with involvement of the pancreas. This was 7.26 per cent of the total number of cases. There were 5 cases (3.45 per cent) of epidermoid carcinoma, 29.41 per cent of the total number which demonstrated metastases. There were no cases of adenocarcinoma. The undifferentiated group had 12 cases (17.78 per cent) of 70.59 per cent of the total number.

The spleen was involved in 14 cases, there being an almost equal number of epidermoid carcinoma and undifferentiated. There were 7 (4.82 per cent) cases of the former which constituted 50 per cent of the total number of cases. In the latter group there were 6 cases (8.82 per cent), 42.86 per cent of the total. In the adenocarcinoma group there was only 1 case (4.76 per cent) constituting 7.14 per cent of the total.

SUMMARY

[illegible]		[illegible] 234		OCHSNER AND DEBAKEY [illegible]		ATKINS AND WAGNER 74		KOLETSKY 125		JAMIESON 40		TENZEL 192		MILLER AND JONES 808		MULLIGAN AND HARPER 44	
		No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
Site of origin	Rt	138	58.97	2,719	58.3	15	60.00	81	64.8								
	Lt	96	41.03	1,987	41.6	29	40.00	44	35.2								
Liver		[illegible]	8.46	1,577	[illegible]			50	40.0	35	87.5	71	[illegible]	248	30.00	21	47.73
Adrenals		[illegible]	[illegible]	[illegible]	17.6	32	43.00	47	37.6	29	72.5	59	30.72	79	9.70	19	43.18
Kidneys		66	28.21	412	10.0	29	40.00	27	27.0	23	57.5	35	18.23	122	15.10	11	25.00
Bone		41	17.52	526	20.4	21	28.00	25	20.0	11	27.5			[illegible]	10.10	15	34.10
Lung		[illegible]	[illegible]			24	32.00	29	23.2	10	25.0	52	27.08	[illegible]	21.00	9	20.45
Heart																	
Pericardium		26	11.11	620	13.1	31	41.87	15	12.0	2	5.0	59	30.72	22	2.70	5	11.36
Major vessels																	
Pleura		26	11.11			33	45.00					[illegible]	27.60	285	35.20	14	31.82
Brain		19	8.1	653	13.8	18	24.00	10	5.2	15	37.5	23	11.90	77	9.50	18	40.97
Miscellaneous		5	[illegible]			52	70.20	64	51.2	13	32.5	117	60.94	37	4.58	21	47.72

There were 8 cases or 3 41 per cent of the total number of cases in which metastases to the skin were found It is stated that metastatic nodules in the skin should be considered from the bronchus until proved otherwise Six (4 14 per cent) were of the epidermoid carcinoma group 75 per cent of the total number There were no cases in which adenocarcinoma was found Two (2 84 per cent) were in the undifferentiated classification constituting 25 per cent of the total

Metastases to the bowel are infrequent, but do occur We had 5 cases or 2 13 per cent to the large and small bowels The small bowel, especially the duodenum, was the most frequent site of involvement Two cases (1 38 per cent) or 40 per cent of the total were epidermoid carcinoma, while the undifferentiated class constituted 3 (4 41 per cent) cases or 60 per cent adenocarcinoma was conspicuous by its absence

There were 3 cases of metastases to the prostate, 1 28 per cent of the entire number of cases There was 1 (0 69 per cent) in which epidermoid was the predominating cell type, no cases in which adenocarcinoma metastasized, the undifferentiated carcinoma metastasized in 2 cases (2 84 per cent) or 66 67 per cent of the total

The diaphragm was involved in only 2 cases This was equally divided between the epidermoid and undifferentiated group This constituted 0 69 per cent of the former cell type, and 1 47 per cent of the latter cell type

The thyroid gland was involved in 2 cases or 0 85 per cent in which there was 1 case (0 69 per cent) of epidermoid carcinoma and 1 case (1 47 per cent) of undifferentiated carcinoma

There was 1 case of metastases to the testicle which was 0 43 per cent of the total number of cases This was a case of an undifferentiated carcinoma or 1 47 per cent of this cell type number

The gall bladder was involved in only 1 case or 0 43 per cent of the total number of cases This was in the epidermoid class or 0 69 per cent

CONCLUSIONS

1 Metastases play an important role in the treatment of bronchiogenic carcinoma since the advent of surgery for this condition

2 There is no organ or structure in the body which escapes metastases

3 Metastases may occur in any of the established ways (1) direct extension, (2) lymphogenous dissemination, (3) hematogenous dissemination (including vertebral veins), (4) direct implantation, and (5) bronchiogenic spread

4 Carcinoma of the lung occurs with almost equal incidence on either side

5 The simplest classification is epidermoid, adenocarcinoma, and undifferentiated However, combinations of these do occur and would be difficult to fit into this arbitrary categorization

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PULMONARY BLASTOMYCOSIS

THE INFLUENCE OF THE IMMUNOLOGIC FINDINGS ON THE SELECTION OF PATIENTS FOR OPERATION

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INFECTIONS of *Blastomyces dermatitidis* in man are serious, and, when disseminated, the survival rate is only 7 per cent[2] [3] In some cases the only residual clinical manifestation of a generalized infection may be in the lung Efforts in the past directed toward the surgical treatment of the pulmonary form of the infection have been almost uniformly poor[1] [4] [5] In spite of this poor record it was thought that there were certain instances where careful immunologic evaluation of the patient might make the deliberate surgical excision of these localized pulmonary lesions feasible In Duke Hospital two such cases were submitted to surgery A report of this experience is recorded in this paper

CASE REPORTS

CASE 1—C W Four months before admission to Duke Hospital this 36 year old white man developed a severe respiratory infection that was associated with severe left anterior chest pain Shortly thereafter he began to cough and spit up blood Afternoon temperature elevation and profuse night sweats then developed After this the patient's course was steadily downhill, in spite of treatment with penicillin, various sulfa compounds, and Aureomycin

Past history and review of systems did not reveal anything of importance The patient was a farmer

Physical examination on admission showed a temperature of 38° C, pulse 100, blood pressure 106/62, and respirations 18 The chest examination showed signs of consolidation in the right upper lung field The urinary tract and skeletal system were normal

Laboratory studies revealed a hemoglobin of 10 Gm , white blood count of 14,000 with 80 per cent segmented forms, 3 per cent eosinophils, 6 per cent monocytes, 10 per cent small lymphocytes, and 1 per cent large lymphocytes The urine showed a specific gravity of 1 010 with albumin, sugar, and microscopic sediment study negative Blood chemistry showed total plasma proteins 7 3 Gm , albumin 2 9 Gm , and globulin 4 4 Gm Examination of numerous sputum smears showed typical *Blastomyces dermatitidis* organisms The complement fixation test was *negative* Repeated skin tests with blastomycin were negative Other skin tests with histoplasmin and coccidioidin were negative, but a 1 1000 old tuberculin skin test was positive

X-ray examination of the chest showed a consolidated area in the left lung field which was confined mainly to the anterior and lingular segments of the left upper lobe (Fig 1)

On bronchoscopic examination purulent secretions were noted coming from the left upper lobe

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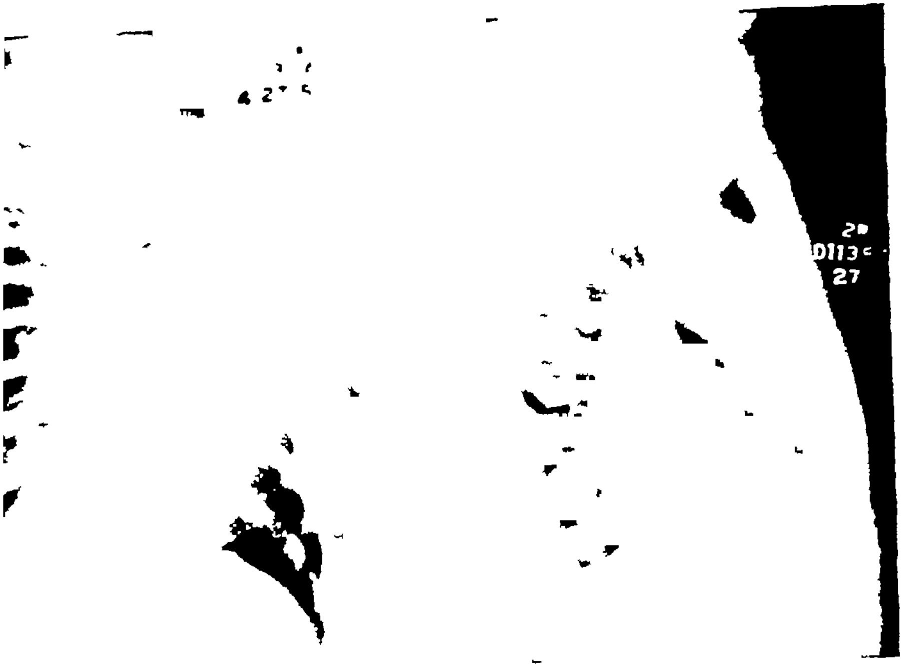
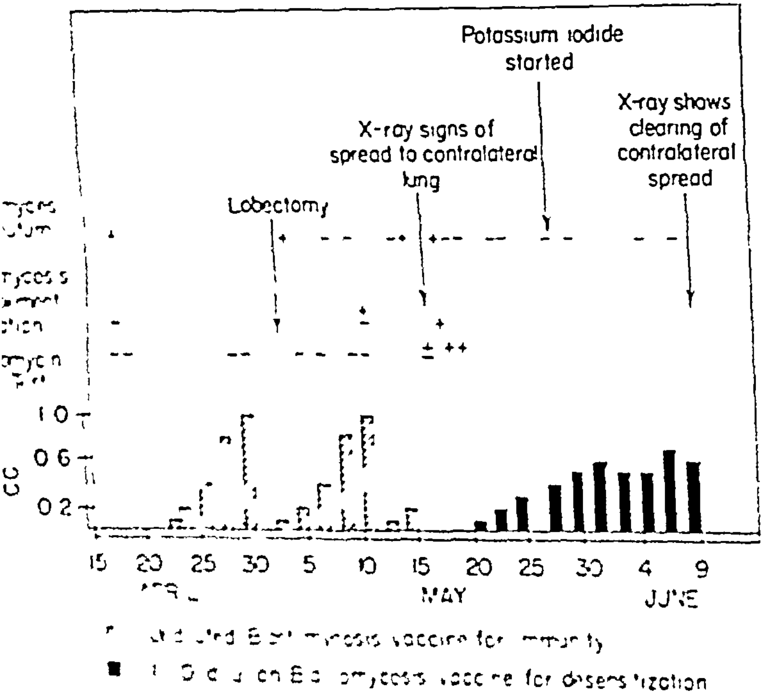


1 Film of patient C W with *Blastomyces dermatitidis* Infection (Case 1)



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Hospital Course—As seen in Chart 1 immunization with blastomyces vaccine was begun one week after admission because of the negative skin test and negative complement fixation. The schedule of vaccine administration was 0 1 c c increasing by 0 1 c c every other day until a daily dose of 1 c c was given. Repeated immunologic studies at the end of the first course of treatment were unchanged, but it was decided to go ahead with the lobectomy Sixteen days after admission the left chest was explored and the involved left upper lobe was removed Studies by the pathologist showed extensive lung destruction and microscopic changes consistent with *Blastomyces dermatitidis* infection Four days after starting a third course of vaccine, or the thirteenth postoperative day, the skin test did become positive It was at this time that the chest plate showed an area of infiltration in the right mid lung field, the complement fixation test also became positive

On the nineteenth day after operation desensitization to the blastomycin was started with a 1 10 dilution given every other day for the next three weeks On the twenty sixth day after operation potassium iodide therapy was started and continued in the postoperative period

Very shortly after the appearance of the positive skin test and complement fixation the lung lesions began to subside On discharge from the hospital forty nine days after operation the lungs were clear, and the patient had no symptoms

One month after discharge he was readmitted because of abdominal pain An appendectomy was done, but a normal appendix was found There was no evidence of any mycotic infection A wound infection developed and was drained by his local physician This cleared in a very short time

His last visit to the outpatient department was on Feb 24, 1953 The patient had epigastric distress typical of a duodenal ulcer This was proved by x ray studies The chest was clear on physical and x ray examination Complement fixation and sputum studies were negative

CASE 2—J H, a 41 year old Negro man, was admitted to the hospital complaining of chest pain, wheezing, and general malaise Symptoms had begun five months before admission when he noted marked fatigability One month after the onset of the symptoms he had to stop work and for the first time developed fever On penicillin therapy he improved for three weeks, but then the symptoms recurred Then he noticed a cough productive of purulent sputum and severe anterior chest pain In spite of further treatment with antibiotics the symptoms increased Careful studies of sputum failed to show any acid fast organisms He lost fifteen pounds in this five month period

The patient was employed in a woodworking plant and was a part time barber Past history and review of systems were noncontributory

Physical examination showed the blood pressure to be 130/90, pulse 90, respirations of 18, and temperature of 37 6° C Examination of the chest showed signs of consolidation of the right upper lung field There was no involvement of the osseous system or genitourinary tract

Laboratory examination showed the hemoglobin to be 8 9 Gm White blood count was 24,000 with 80 per cent segmented forms, 6 per cent stabs, 1 per cent eosinophils, 5 per cent monocytes, 4 per cent small lymphocytes, and 4 per cent large lymphocytes The urine examination was negative Blood chemistry studies showed the total plasma proteins to be 6 7 Gm with an albumin of 3 00 Gm and a globulin of 3 7 Gm

Smears of the sputum on admission were positive for *Blastomyces dermatitidis* and this was later confirmed by culture Skin test to blastomycin six days after admission was positive Complement fixation studies for blastomyces were negative X ray films of the chest showed diffuse consolidation of the right lung with involvement of both the upper and lower lobes (Fig 2)

Hospital Course—Eight days after admission a course of blastomyces vaccine therapy for desensitization was started (Chart 2) The initial injection of vaccine was 0 1 c c and this was increased by 0 1 c c every other day until the sixteenth day after admission when 1 c c was given

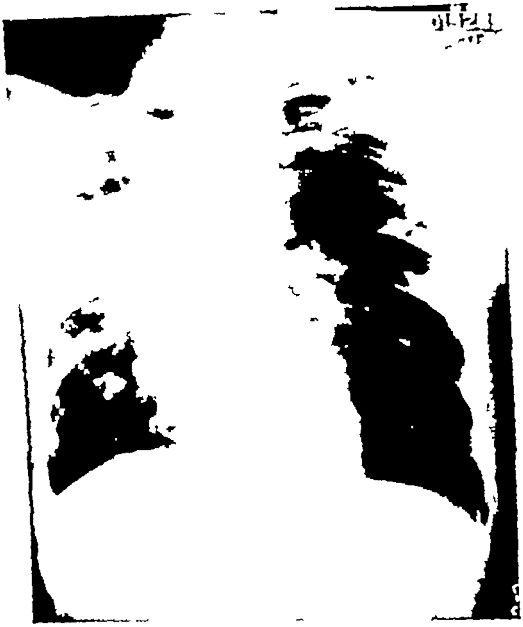
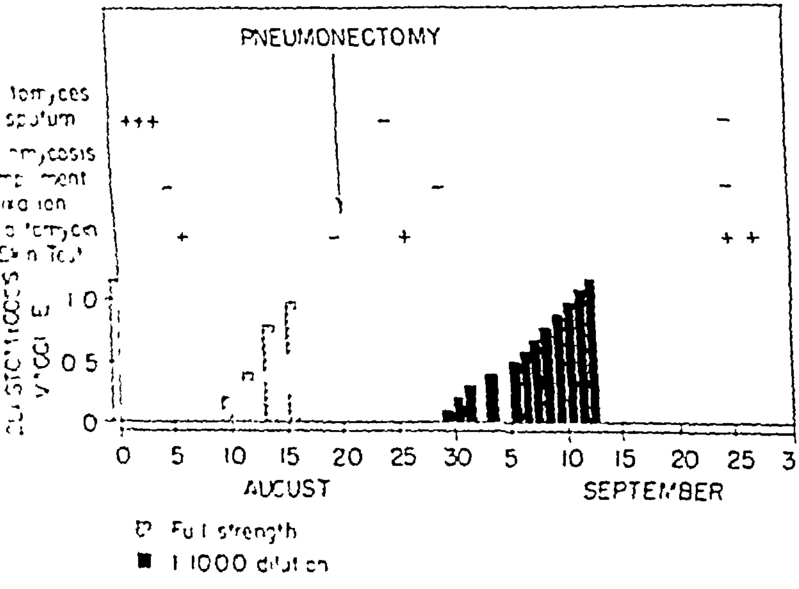


Fig. —Film of patient J. H. with *Blastomyces dermatitidis* infection (Case 2)



[illegible]

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One month after discharge the patient was seen in the outpatient clinic. He had just completed desensitization with blastomyces vaccine, and the skin test was negative On another visit five months after discharge the skin test was positive

The patient was last seen in the clinic eighteen months after operation with no complaints He had gained ten pounds, the sputum was negative to smear and culture, and the left lung was clear

DISCUSSION

The patients in the two cases presented in this report recovered following the deliberate surgical extirpation of lung infected with blastomycosis The fortunate outcome in our cases was due to the favorable immunologic response of the patients to the infection In Case 2, the patient had a positive blastomycin skin reaction and a negative complement fixation reaction to blastomyces Vaccine therapy was begun to desensitize the patient before surgery so that there would not occur a hypersensitive reaction to a postoperative spread The patient's skin test was converted to negative In view of this response as well as the lack of involvement of other structures, pneumonectomy was done

The patient in Case 1 on admission had a negative skin test to blastomycin and a negative complement fixation to blastomyces Surgery in this instance was begun before either became positive A postoperative spread of the infection occurred and cleared when the complement fixation and skin test became positive In retrospect the operation should have been deferred until the skin test became positive The rapid change in the postoperative pulmonary infiltrate was striking and lends further proof to the observation that immunologic findings are sensitive indicators of prognosis

In 1949 Smith[5] reviewed the immunologic findings in forty blastomycosis patients followed at Duke Hospital The study correlated the response to treatment and survival rate with the results of the blastomycin skin test and the complement fixation test for blastomyces This series of forty cases of blastomycosis was found to fall into the following four separate categories

1 Positive Skin Test with Negative Complement Fixation This indicates good immunity and of the ten patients in this category studied by Smith nine survived

2 Positive Skin Test and Positive Complement Fixation Test In this group there is immunity but the positive complement fixation indicates active disease In Smith's study of this group of ten there were seven survivors

3 Negative Skin Test but Positive Complement Fixation The results in this group were very poor, there being only two survivors in ten cases The poor prognosis is explained on the advancing active disease indicated by the positive complement fixation associated with anergy indicated by the negative skin test The anergy is similar to the terminal anergic state in some patients dying from disseminated tuberculosis

4 Negative Skin Test and Negative Complement Fixation In nearly every instance this indicates, according to Smith, disease of short duration There were eight survivors in ten cases of Smith's belonging to this category

As outlined, the clear understanding of the immunologic responses of the patient to the blastomycosis infection governs the therapy with blastomycosis vaccine and iodide. It may be necessary to use the vaccine to promote immunity in some situations or to desensitize the patient in other cases. Iodide therapy can be of benefit in the treatment of the disease, but the skin test and complement fixation reaction must govern its use. If iodide is administered to a patient with a low level of immunity dissemination of the disease, as emphasized by Smith, may occur. The positive skin test and complement fixation are indications of immunity. On the other hand, hypersensitivity to blastomycosis may lead to difficulty with iodide due to dissemination of the products of the blastomycosis infection in a hypersensitive patient. These considerations lead to therapeutic regimes that may appear paradoxical as in Case 1. It may be necessary to use vaccine to incite immunity that at the same time may induce hypersensitivity. Then before giving iodide to the patient with induced hypersensitivity the desensitization with the same vaccine will have to be performed.

Iodide was used in one of the two cases recorded in this report. It was started in Case 1 in the postoperative period only after the patient had shown signs of immunity and then had been desensitized. In Case 2 the patient's progress was so good that it was never deemed worth while to use iodide.

The introduction of therapy with stilbamidine in blastomycosis has altered greatly the treatment of the disease.[4] In the generalized form that is almost uniformly fatal this therapy has in our hands been successful. In eight such cases recovery has occurred, and there has been no relapse over a short follow-up period. Unfortunately there is associated with this treatment a high incidence of trigeminal neuropathy. This has developed in six of our eight cases. Schoenbach, Miller, and Long[4] note and discuss this complication in their paper. In certain selected cases where only the lungs were involved and there was adequate immunity as indicated by a positive skin test to blastomycin one might consider resection alone. The stilbamidine could be saved for use if complications developed. Pulmonary resection may have to be done eventually in stilbamidine-controlled cases, particularly if there occurs extensive lung destruction.

CONCLUSION

Two cases of *Blastomyces dermatitidis* infection of the lung treated by surgical resection are reported. The correlation between the good results and immunologic responses of the patients is presented.

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BRONCHIAL RESECTION AND ANASTOMOSIS

Report of a Case

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MUCH interesting work has been done in the field of reconstructive tracheo bronchial surgery in the last few years Many points, however, need more precision and further study This is the reason I have reported this case, in the hope that it may add a little to the knowledge of the question

CASE REPORT

E B , a 52 year old white man, a barber by trade, was admitted to this hospital on Jan 15, 1951 Past history revealed that two of his brothers had died of pulmonary tuberculosis At the age of 30 he had been hospitalized for a pulmonary ailment of an unknown nature Since then he had been subject to attacks of flu with fever and coughing In November, 1945, after an especially severe bout of flu, he presented himself at one of the tuberculous diagnostic centers A cavity was found at the apex of the left lung He was sent home to rest while waiting for a place at the sanatorium He was finally admitted in February, 1946 Strict bed rest was enforced until August of the same year At that time the cavity had disappeared, the basal sedimentation rate was at 4 mm , the sputum and gastric contents contained no tubercle bacilli General condition was good, but the physician in charge of the case at that time noted an insufficiency of the respiratory function The patient was discharged with a diagnosis of moderately advanced, nonbacillary, inactive, ulcero fibrous tuberculosis

Rest was continued at home for four months After this time he went back to work Gradually he felt more and more tired and noticed that the cough was increasing in intensity, and the sputum in quantity

In September, 1950, he had to stop work and stayed at home until re admission to this hospital, in January, 1951 Upon admission he was very thin and weak, the basal sedimentation rate had gone up to 45 mm , the hemoglobin had come down to 75 per cent The x ray examination revealed a cavity at the left apex, and a bronchiogenic spread in both lung areas Sputum examination revealed a high content of tubercle bacilli Bed rest was again started but this time with the addition of 1 Gm of streptomycin daily Gradually the lung fields cleared, but the cavity in the upper left apex increased in size In July, a pneumoperitoneum was started, but had to be discontinued in October, because of gastric distress A bronchoscopy performed in December, revealed a normal right bronchial tree On the left side, a stenosis of the main bronchus was noted, secretions appearing through a pinhole in the center of the constricted area

A repeat bronchoscopy in January, 1951, revealed an identical picture

Tomography revealed no cavity on the right side The electrocardiogram revealed a sinus arrhythmia, and a myocardium of doubtful integrity

On February 14, the patient was presented at the joint medical surgical meeting for study He appeared as a thin man, older in appearance than in years, with palpable radial and temporal arteriosclerotic arteries It was quite apparent, although complete respiratory function studies were not performed that this man was in very great need of every bit of normal lung tissue available He wanted something done to correct his present status He

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[illegible] for surgery preferably for resection (due to the bronchial stenosis and the two [illegible] the upper lobe and the apical segment of the lower lobe) (Figs 1 and 2)

On Feb [illegible], 195[illegible] the left chest was entered through the bed of the resected fifth rib [illegible] apparent that the whole upper lobe and the apical segment of the lower lobe [illegible], due to their gross involvement in disease This was done quite easily [illegible] technique The remaining segments of the lower lobe appeared perfectly normal [illegible] no palpable nodules We were now in this situation The diseased tissue [illegible] removed but the stenosis remained between normal bronchus and normal lung tissue [illegible] As it was strongly felt that this particular patient needed the four basal segments it was decided to attempt a resection of the stenotic area, with end to end anastomosis [illegible]

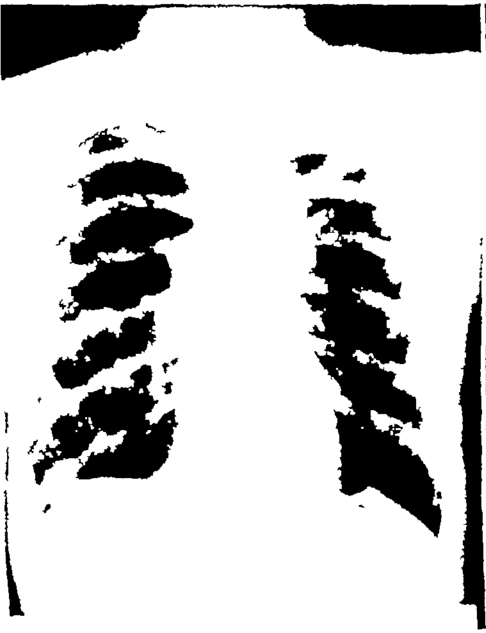

FIG. 1

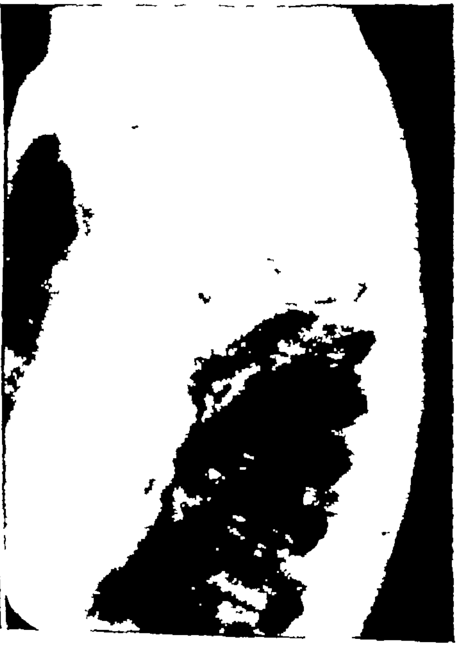

FIG. 2

[illegible] taken on Jan [illegible] — Two different fluid levels can be [illegible] annular contour [illegible] It shows very well the two distinct [illegible] apical segment of the

[illegible] The lower lobe [illegible] apical segment (Fig 4) [illegible] difficulty [illegible]

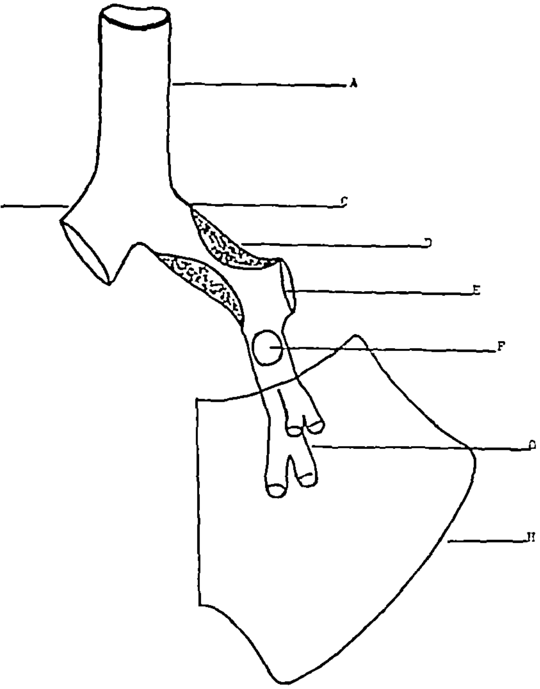

Fig 3

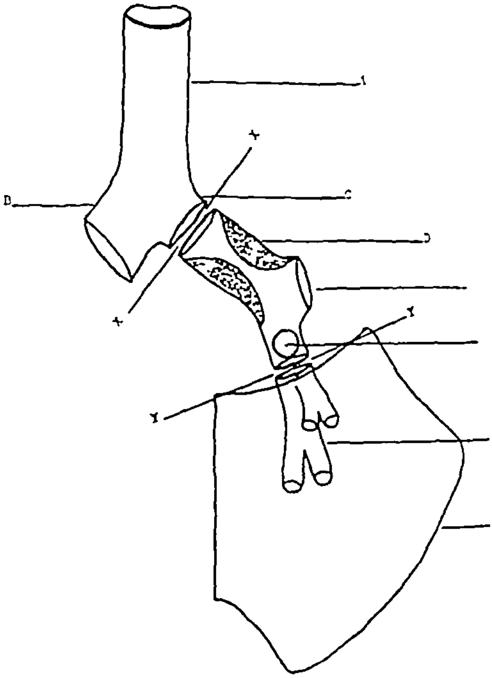

Fig 4

Fig 3 —*A*—trachea *B*—right main bronchus *C*—left main bronchus *D*—stenotic area. *F*—orifice of resected left upper lobe *F*—orifice of resected apical segment of left lower lobe *G*—four basal bronchi *H*—normal lung tissue.

Fig 4 —*A*—trachea *B*—right main bronchus *C*—left main bronchus *D*—stenotic area *E*—orifice of resected upper lobe *F*—orifice of resected apical segment, *G*—four basal segments *H*—normal lung tissue X X—line of section Y Y—line of section

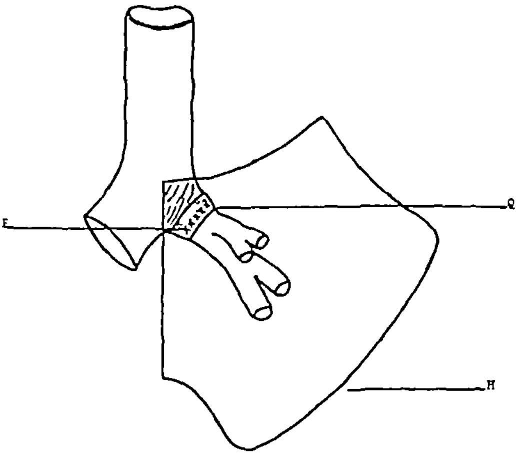

Fig 5 —*Q*—line of anastomosis *I* —covering pleural flap

Difficulty in expectorating was soon noted, and quite a few bedside bronchial aspirations had to be performed. Otherwise the postoperative course was normal.

By the sixth postoperative day (Fig 7) there was fairly good lung expansion, and the breath sounds were becoming clear and normal.

The lower drainage tube was removed after seventy two hours. The upper tube was left in for eight days in the event that a leak might occur in the anastomosis. However, there was no sign of this at any time.

One month after operation, 150 c c of clear fluid was removed from the upper chest. This was negative for all organisms including tubercle bacillus.

By March 21 the patient had gained weight, could expectorate easily and there were very few secretions. Temperature was normal. A first sputum examination was negative. A week later this was positive.

Fig [illegible]

Fig [illegible]

Fig [illegible] — X-ray film taken on the [illegible] postoperative day
Fig [illegible] — X-ray [illegible] on the sixth postoperative day

[illegible] shown in Fig [illegible] was taken two months after the operation, at this [illegible]

[illegible] a very well healed anastomosis and a slight narrow[illegible] were negative for Koch's bacillus [illegible] vital capacity of 2100 c c [illegible] patient three months postoperatively [illegible] discharged [illegible] he was suff[illegible] for the last [illegible]

On June 16, he complained more intensely of this thoracic pain, and coughed up 50 c c of bright red blood A tomogram was taken at this time to see if it would shed light on whatever process was going on (Fig 10)

We were thinking of an exploratory thoracotomy when, on June 19, the patient had a massive hemoptysis and died An extract from the post mortem report is included here

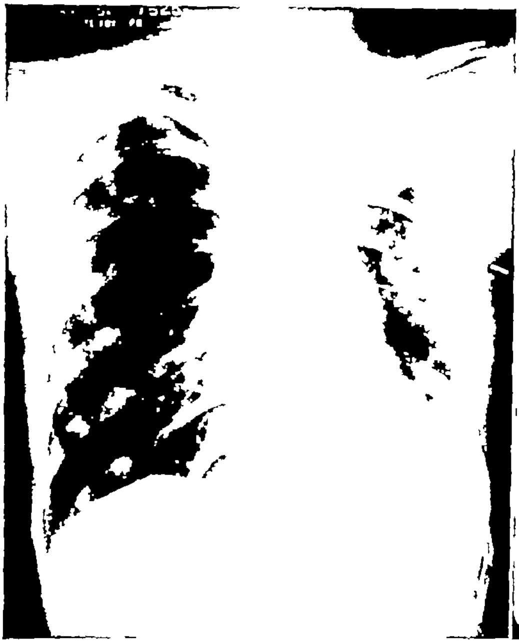

Fig 8

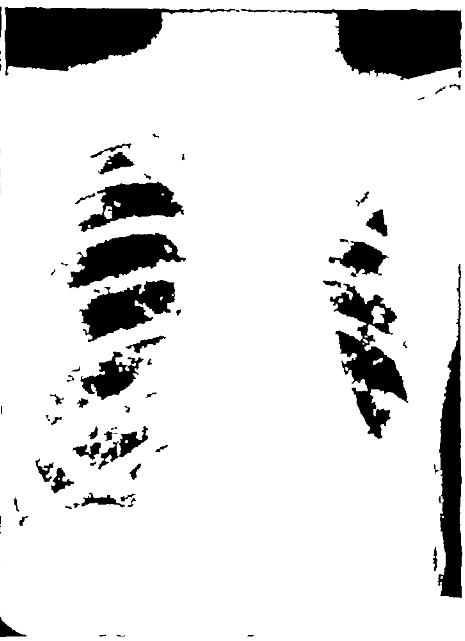

Fig 9

Fig 8 —X ray appearance two months after the operation with a fair quantity of normally aerating lung tissue on the left There is a left paratracheal shadow which was taken to be part of the normal healing process

Fig 9 —X ray appearance three months postoperatively

Thorax —

Right Side A few adhesions were present between the apex and the parietal pleura and between the base and the diaphragm Grossly, the lung was normal Histologically, *the lung contained a few tuberculous micronodules in a progressively fibrotic stage*, a moderate anthracosis, and a purulent bronchiolitis

Left Side The apex was fixed to the thoracic wall by a very dense and thick fibrous process A scalpel had to be used *for cleavage There existed to the left of the arch* of the aorta, between that structure and the lung surface, a hard fibrotic mass This extended from the thoracic vault to the lower lobe and was very adherent to the mediastinum and to the superior and posterior parts of the aorta The center of this mass contained about 5 c c of thick pus (This later was reported as sterile) The lung itself, reduced to two fifths of its original size, was red, firm, and presented, in the region of the apical segment an organizing hematoma This seemed to have infiltrated its way into the lung substance

Trachea and Bronchi —These were filled with blood The bronchial anastomosis was perfectly well healed and presented a normal mucosa There was slight narrowing of the lumen.

The Aorta —Presence of a few atheromatous plaques In the posterior region of the arch, the aorta is very adherent to the vertebral bodies Its wall at this level seems to be [illegible] in different layers and this is in close association with the fibrous mass already described [illegible] the [illegible] in the surface of the lung. An inflammatory process shows the [illegible] of the elastic medial layer of the aorta.

The examination of the other organs was noncontributory.

Post Mortem Diagnosis.—Aortic aneurysm ruptured into the surface of the segmented lobe of the left lung was the diagnosis.

Fig. [illegible] appear at the left of the trachea immediately above the [illegible]. This [illegible] hematoma [illegible] tomographic cut.

DISCUSSION

This case certainly brings up the question which concerns a number of the patients discharged from sanatoriums after medical treatment who show up later with progressive disease. It seems that about 30 per cent of these patients eventually return for further treatment. This shows the necessity of active [illegible] in more cases. At the time of this patient's first discharge [illegible] tomograms were not in use and no cavity could be seen on [illegible] x-ray films and there were no clinical signs of activity. Now there is [illegible] discharged a patient without a tomographic study of the lungs [illegible] signs.

[illegible] this patient should have had a tracheotomy at [illegible]. It would have aided greatly in the postoperative [illegible] is impossible to say. [illegible] this patient for [illegible] all the absolute indications for this procedure We have not come to any conclusion regarding the formation and rupture of this aortic aneurysm We are ready to accept the blame in the line of faulty technique, but we have reviewed this time and again and do not see that we could do better at another opportunity Possibly we would try to cover the raw area left by the eradication of the apical segment Can this be incriminated as a causative factor? It is possible, but we do not believe very probable, unless the vessels were already diseased

At the time of operation we had noted nothing irregular about the appearance of the aorta

We believe, that in such an operation, a marked inflammatory reaction is inevitable, and if it occurs alongside normal vessels, all will be well, but if it occurs close to an already pathologic aorta, this may be fatal

CONCLUSIONS

1 Resection and end-to end anastomosis of bronchi for tuberculous stenosis is a fairly easy procedure, and must be superior to grafts and prostheses

2 Tracheotomy should be employed as part of the postoperative therapy

3 Cases should be selected if possible, better results will probably be obtained in younger people

4 Great care should be exercised in the technique in order not to let vascular structures come into contact with raw areas

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DILATATION OF MAJOR AZYGOS VEIN SIMULATING A MEDIASTINAL TUMOR

A CASE REPORT

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THERE has been an increasing interest in the significance of mediastinal masses in the past several years, due no doubt to the more frequent use of chest roentgenograms coupled with the greater safety of exploratory thoracotomy. It would seem appropriate, therefore, to report a case of dilation of the azygos vein which simulated a mediastinal tumor on the chest x-ray film.

CASE REPORT

Mrs. M. P., Case Number 10410, a married woman 51 years of age, was admitted to [illegible] Hospital on March 7, 1951, with the following history.

In January, 1951, a routine chest x-ray picture taken by the mobile unit revealed a [illegible] in the right upper mediastinum. She had no complaints and had always been in excellent health. She had had four normal pregnancies. The children were all alive and ranged in age from 12 to 21 years of age. One sister had died of tuberculosis.

Physical examination was negative except for marked obesity. The patient's weight [illegible] pounds; she was 64 inches tall. She had a hypertension of 190 mm. of mercury systolic and 110 mm. of mercury diastolic. X-ray photographs taken by her local physician [illegible] anterior, lateral and oblique views revealed a shadow of uniform density [illegible] margin located just to the right of the mediastinum at the level of the major [illegible] but lying posterior to the trachea. The mass was somewhat pear shaped with [illegible] end pointing toward the mediastinum. It did not exhibit expansile pulsations [illegible]

The tentative diagnosis was either a cyst or a tumor of lymphoid origin. Exploratory [illegible] on March 8, 1951. A long posterolateral segment of the right [illegible] and the pleural space entered through the bed of this [illegible] entirely normal. The tumor mass was easily visualized in the region [illegible] the vertebral bodies posteriorly and the trachea anteriorly [illegible] to be filled with dark fluid. It measured [illegible] The mediastinal pleura was dissected from the [illegible] this point the tumor was found to consist of a marked [illegible] The vein narrowed down in a funnel shaped manner at its [illegible] The vein was ligated and divided. At this point [illegible] the arch of the azygos vein [illegible] the anterior [illegible] was very difficult and during the course of this [illegible] Bleeding could readily be controlled by [illegible] arterial [illegible] During [illegible]

[illegible]

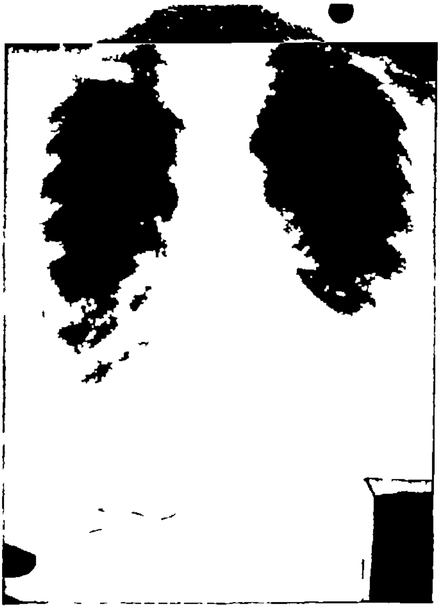

Fig 1.—Preoperative chest x ray picture March 1951 showing oval shadow of increased density projecting to right of mediastinum opposite the shadow of the aortic nob

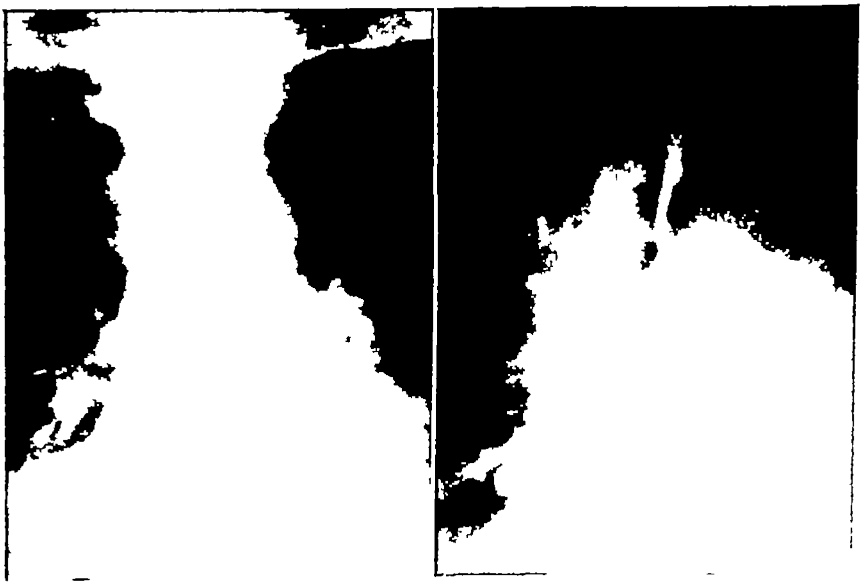

Fig 2

Fig 3

Fig 2.—Close up view of lesion seen protruding to right of mediastinum at level of aortic arch (preoperative)

Fig 3.—Preoperative lateral view of lesion with barium in esophagus

[illegible] on March 14. Postoperative chest x-ray films were taken in July, 1951. The [illegible] which had been present previously can no longer be visualized (Fig 4). The patient has remained well since her surgery. Studies of the venous pressure in the upper extremities done postoperatively are within normal limits.

ANATOMY

The terminal segment of the major azygos vein can be visualized as a small round shadow producing an indentation on the right posterolateral aspect of the barium-filled esophagus in the right anterior oblique view.[1] The tributaries of the azygos vein may show considerable variation[2], however, the terminal segment is more constant. Anatomically the terminal segment of the major azygos vein consists of the portion contained between the point at which the vein leaves the posterior thoracic wall and the point at which it terminates in the vena cava superior.

[illegible] showing absence of mediastinal shadow

Studies by Andreassi show that the azygos vein leaves the posterior thoracic [illegible] anterior portion of the body of the fourth dorsal vertebra [illegible] anteriorly to the right describing a curve with its concavity [illegible] laterally to the esophagus and trachea and again medi[illegible] superior vena cava. The entrance into the superior vena [illegible] lower level than the point at which it leaves the posterior [illegible] curved plane the central portion of the vessel [illegible] in the usual sagittal projection (the [illegible] oblique projection and the anterior por[illegible]

DISCUSSION

In this case no cause was found to explain the marked increase in size of the azygos vein Increase in size of the image of the azygos vein has been demonstrated frequently in portal stasis Grilli[4] has been able to demonstrate significant enlargement of the azygos vein shadow in six out of ten patients with esophageal varices In the latter condition the azygos vein, along with the esophageal veins, becomes important as part of the collateral circulation In any cardiac or extracardiac disease that increases the venous pressure in the vena cava superior the azygos vein will enlarge Durieu and Lequime[5] have demonstrated visible enlargement of the azygos vein in cardiac insufficiency with decrease in the size of the x-ray image following correction of the decompensation The azygos vein acts as a manometer, signaling the pressures in the vena cava Variations in size of the image of the azygos vein have been studied and observed in physiologic conditions An increase occurs during the Valsalva test with changes of body position, in physical exercise, and in phases of cardiac activity

I can find no reports in the literature in which the terminal segment of the major azygos vein has become dilated so as to cause a roentgen shadow which is of such size as to simulate a mediastinal tumor It is possible that examination of this mass fluoroscopically with the patient straining, so as to increase the venous pressure, would have demonstrated an appreciable increase in the size of the shadow This is suggested as a worth while diagnostic procedure

Planograms have been of help in separating the image cast by the normal azygos vein from opacities due to tuberculosis[6] and might well have produced valuable information as to the nature of this lesion Unfortunately, these studies were not done in this case

SUMMARY

1 A case of abnormal dilation of the terminal segment of the major azygos vein simulating a mediastinal tumor is presented

2 The various causes of dilation of the azygos vein are discussed

3 It is suggested that fluoroscopic examination, in an effort to demonstrate changes in size of the mass with straining so as to increase the venous pressure, as well as planographic studies, be carried out in all lesions visualized in this area on the chest roentgenograms

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NONSPECIFIC LUNG ABSCESS EXPERIENCE WITH FIFTY-FIVE CONSECUTIVE CASES

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INTRODUCTION

THIS communication records our experience with nonspecific lung abscess during the period 1947 through 1952 Fifty-five consecutive cases are reported the patients range in age from 20 to 62 years All of these patients except one were men This series includes those cases with an insidious onset or in which the pathology was secondary to a clinically recognized, pneumonic infectious process We were not able to obtain a history of dental or ear, nose, and throat surgery from any of these patients

No cases secondary to prior disease such as bronchiectasis, carcinoma adenoma lung cyst or tuberculosis are included Amebic lung abscess, occasionally seen in this area is not included because of the difference in pathology No bronchial foreign body cases are included Three cases previously given adequate treatment for lung abscess at other hospitals and who had uneventful removal of residual lesions are excluded The cases reported were either proved pathologically (twenty two) or showed definite radiologic evidence of abscess, such as a thick walled radiolucency with fluid level or a rounded infiltration [illegible] necessarily conforming to a bronchopulmonary segment

LITERATURE

In reviewing the American literature Allen and Blackman[1] collected 2 114 [illegible] up to 19[illegible]6 and found the reported mortality for cases treated by medical methods to be [illegible]4 4 per cent and medical plus surgical methods to be 34 2 per cent Smith[2] collected 2 166 cases reported between 1936 and 1948 and found [illegible] no change in mortality Brock[3] in 1948 emphasized the high [illegible] in lung abscess He pointed out the danger of embolic infection [illegible] particularly the brain, and the continuous disability resulting [illegible] He also discussed the factors involved in deciding the [illegible] other authors have reported widely varying experi[illegible] drainage procedures medical treatment [illegible] methods of treatment includ[illegible] or suddenly in full-blown form, probably as the result of foreign body, aspirated infected material, or embolism. Patients with this condition are supposed to exhibit high fever and cough with production of purulent sputum, which may or may not have a foul odor. Pain and hemoptysis may be present. If the abscess does not connect with a bronchus, there will be much less sputum, however, the breath may be foul regardless.

Even before the widespread use of short courses of antibiotics for pulmonary infections, various observers[2-5] noted that an occasional patient with this serious condition would show little or nothing in the way of toxicity or presenting symptoms. We have been impressed with the frequency of this situation in the cases seen here in the last three years.

TABLE I. SYMPTOMS

PERIOD	NO. OF CASES	FEVER	CHILL	WT. LOSS	COUGH	CHEST PAIN	HEMOPTYSIS	FOUL SPUTUM	TOXIC ON ADM.	MINIMAL SYMPTOMS
1947-49	26	23	16	10	23	20	6	20	20	4
1950-52	29	23	7	10	24	24	16	18	12	12
Total	55	46	23	20	47	44	22	38	32	16

Table I shows the symptomatology of our cases, with the cases divided into two nearly equal three-year groups. There was not much difference in kind of symptoms, although there seems to be an increase in hemoptysis. However, the number of cases whose symptoms were minimal, or not indicative of an abscess clinically, has practically tripled, while the number of cases considered toxic (temperature over 101° F., white blood count over 16,000) before start of treatment has decreased to less than one-half (twelve of twenty-nine). We can assume that chronic lung abscess still carries a poor prognosis and remains fraught with secondary dangers if untreated, therefore, any pulmonary symptoms, even if not marked, deserve radiologic examination. Patients with pulmonary infiltrations treated with antibiotics should, of course, be carefully followed until complete radiologic clearing has occurred, as secondary abscesses may thus be treated promptly. Early bronchogenic tumors presenting as localized pneumonitis may also be identified.

TABLE II. LOCATION OF LESIONS BY LOBE INVOLVED

PERIOD	R.U.L.	R.M.L.	R.L.L.	L.U.L.	LINGULA	L.L.L.	TOTAL
1947-49	6	3	7	5	0	5	26 Abscesses 26 Patients
1950-52	16	4	3	4	0	4	31 Abscesses 29 Patients
Total	22	7	10	9	0	9	57 Abscesses 55 Patients

We have noticed a tendency in the last few years for these lesions to appear in the upper portions of the lung, particularly the right upper lobe (see Table II). The explanation of this is not entirely clear and no illumination on this point is offered in the reviewed literature. Infected material certainly would be more easily aspirated on the right side, but why 40 per cent of this series should have presented in the right upper lobe is not explained. If this is a true finding it suggests that patients with acute cavitary upper lobe lesions and with sputum free of tubercle bacilli should be subjected to abscess therapy without delay. Fig. 1 shows presenting symptoms in relation to location of disease. One significant finding concerns the large group of right upper lobe cases: although exhibiting about the same amount of pain, seemed to have a lower incidence of foul sputum and initial toxicity than the lesions in other lobes. This probably can be explained mechanically, as an upper lobe lesion should drain well as soon as bronchial communication becomes established.

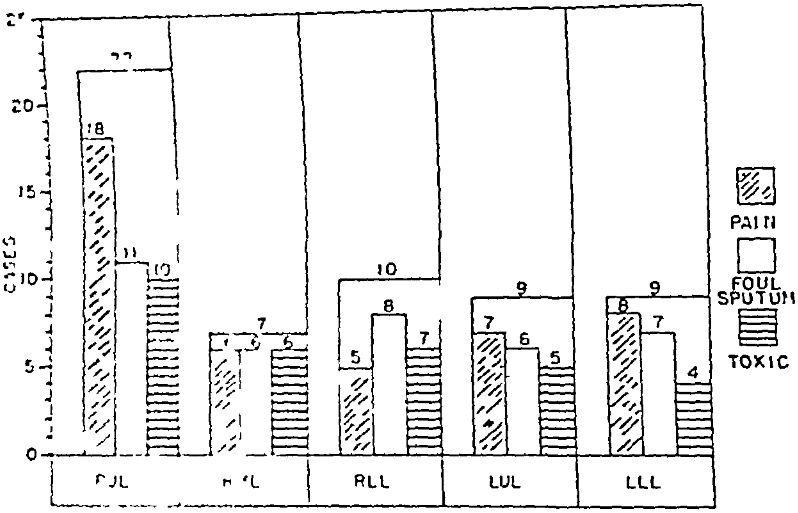

FIG. 1.—Location versus symptoms.

BACTERIOLOGY AND ANTIBACTERIAL TREATMENT

Almost all of these patients had satisfactory cultures made from sputum or bronchoscopic aspiration. Vincent organisms were not routinely looked for by the laboratory. Since they respond readily to penicillin we have not felt it necessary to request this examination. *Staphylococcus aureus* was consistently found with *Streptococcus hemolyticus*, *Pseudomonas aeruginosa*, *Aerobacter aerogenes*, *Hemophilus influenzae* and *Escherichia coli* present less frequently in that order. Fungus cultures have routinely been employed since 1949, but [illegible] been found in conjunction with lung abscess. No matter how long the [illegible] abscess have been present antibiotic treatment is instituted to [illegible] improvement may be obtained. The patients receive at least 1[illegible] units of penicillin per day. Sulfonamides were used in 1947 and 1948 [illegible] for the last four years. If the sputum is not reduced [illegible] in addition [illegible] antibiotic is added which is selected on the [illegible]. Aerosol penicillin has been used in a few cases [illegible] in our experience.

[illegible] ruling out tumors, foreign bodies and [illegible] all but [illegible] of the patients were broncho[illegible] material we did not feel that there was any therapeutic value in bronchoscopy However, in one case where segmental bronchial constriction was present, bronchial dilatation at intervals was of help in obtaining a cure It is our opinion after reviewing the resected material that no case not cured by antibiotic treatment would have been cured by bronchoscopic aspiration and antibiotic instillation

Postural drainage is employed and it is believed to be of benefit depending of course, on the intelligence and cooperation of the patient

DURATION OF DISEASE VERSUS NEED FOR SURGERY

Fig 2 shows the relationship between the duration of symptoms before starting intensive treatment and the eventual need for surgery As would be expected, the long-standing, fibrous-walled lesions usually required surgical treatment After six weeks the value of medical treatment decreased greatly, however, it is felt that antibiotics should be used until no further improvement clinically or radiologically is obtained

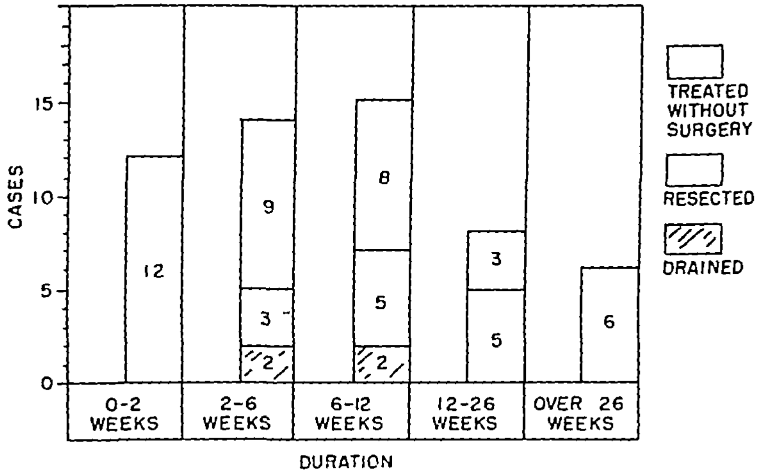

Fig 2.—Duration of symptoms at the beginning of treatment versus the need for eventual surgery

Some patients with long-standing disease were cured by the antibiotic agents, and surgery, when required, was easier with the inflammatory reaction at a minimum Cooperative management between medical and surgical specialists is obviously necessary if fatal outcomes are to be avoided and chronic suppurative situations, difficult to treat surgically, prevented Bronchoscopy, aside from its diagnostic value, may help in localizing the process and directing surgical treatment If there is suspicion that an acute abscess is associated with bronchiectasis, bronchography may be justified, although we do not favor it when pneumonitis is present Small residuals may be evaluated by bronchography, and here it is most useful

OPERATIVE PROCEDURES

Table III shows the operations performed for lung abscess A few drainage procedures for acute lung abscess were done several years ago but none has been necessary recently Primary drainage for acute abscess should not be

TABLE III TYPE OF SURGERY PERFORMED

PERIOD	NO. OF CASES	DRAINAGE	PNEUMONECTOMY	LOBECTOMY	SEGMENT OR WEDGE
1947-49	12	3	3	4	2
1950-52	11	1	0	6	4

forgotten, but may rarely be needed in the future. Pneumonectomy for destroyed lung resulting from an abscess has been necessary in three patients. Earlier treatment might have made such extensive resections unnecessary, as all of these patients had long-standing symptoms when first seen. Our aim has been to remove as little functioning lung tissue as possible when resecting the disease.

RESULTS

Results are shown in Table IV. Of thirty-two patients treated without surgery twenty-eight are considered fully cured and three improved. Two of the latter were improved at the time of discharge, but have been lost to follow-up; one refused surgery and has minimal residuals.

TABLE IV RESULTS

	NO. OF CASES	CURED	IMPROVED	DIED
Without surgery	32	28—88%	3—9%	1—3%
With surgery	23	21—92%	1—4%*	1—4%*

*Treated with drainage.

The patient who died was a young man with lobar pneumonia and septicemia who ran a rapid downhill course despite intensive treatment and died in seven days. The chest x-ray films showed gradually progressing pneumonitis. The diagnosis of abscess was considered but only confirmed at post mortem.

Twenty-three surgical cases produced twenty-one cures. In four of these, secondary drainage or thoracoplasty following resection was necessary for complete cure of empyema or fistula. One patient who had a primary drainage procedure was considered improved when discharged with a draining sinus. He has been lost to follow-up. One patient, an elderly man with senile dementia, treated by drainage, died after a long downhill course.

SUMMARY

1. Fifty-five cases of nonspecific lung abscess are reported.

2. Thirty-two patients were treated with intensive antibiotic therapy alone. Twenty-eight patients were cured, three were improved, and one died.

3. Twenty-three patients required surgery in addition to antibiotic treatment. Lobectomy or segmental resection was done in nineteen patients and primary drainage in four. All resected cases and two of the cases having primary drainage were cured. One patient treated by drainage was improved and one died.

4. [illegible] emphasis on the increased incidence [illegible] advent of widespread [illegible]

5 The value of early intensive antibiotic therapy is demonstrated

6 The value of intensive antibiotic therapy in all cases regardless of duration of symptoms is discussed

7 Bronchoscopy was considered to be essential in the diagnosis of these cases

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MEDIASTINAL LIPOMA

THE SUCCESSFUL REMOVAL OF AN EIGHT POUND ONE OUNCE (3,657 GRAMS) TUMOR

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SINCE the first case of intrathoracic lipoma reported by Fothergill[1] in 1783 a number of surveys of the literature tabulating the total number of cases have been reported. The first comprehensive review of thoracic lipomas was reported by Heuer[2] in 1933. He described three types of thoracic lipomas. In the first group are the "dumbbell" type lipomas with intrathoracic and extrathoracic tumors connected by an isthmus through an intercostal space; in the second group are those which extend into the neck from the superior mediastinum; and in the third group are those limited to the thoracic cavity.

The most recent review of the literature is that of Keeley, Gumbiner, [illegible] and Rooney[3] in March 1953, who state that they have collected a total of fifty-seven cases of intrathoracic lipoma and add one of their own, making a total of fifty-eight cases. The largest tumor recorded was found at autopsy to weigh 17 pounds, 6 ounces.

Watson and Urban[4] in 1944 reported the successful removal of a 6.8 pound mediastinal lipoma and stated that this was the largest mediastinal lipoma which had been excised successfully from the chest cavity and reported in the medical literature until that time.

CASE REPORT

[illegible] housewife, was referred to the St. Joseph Hospital by Dr. [illegible] because of a chest x-ray film taken by a mobile tuberculosis unit [illegible] the left chest. She had noticed gradually increasing dyspnea on [illegible] year. Eight years prior to admission to the hospital she [illegible] she could swim only ten or fifteen yards before becoming [illegible] to the hospital she would become quite dyspneic [illegible]. She had also noticed slight difficulty in swallowing for [illegible]

[illegible] of the right femur at the age of [illegible] year, which had [illegible] of the extremity. She could walk with the aid of a [illegible]

[illegible] well-developed, well-nourished white woman who did [illegible]. Physical findings were confined to the chest [illegible] of the [illegible] displacement of [illegible]. The apex [illegible] was [illegible] right sternal border [illegible] the right lung. There was dullness [illegible]. There was dullness to per[illegible] Breath [illegible] well [illegible] transmitted at the extreme apex of the left chest and over the upper half of the left posterior chest The left upper posterior chest was resonant to percussion The heart sounds were of good quality, the rhythm was regular, there were no murmurs, the pulse rate was 84 per minute, the blood pressure was 126/96 There was no paradoxical pulse The red blood count was 5,010,000, the hemoglobin was 15 5 Gm , the white blood count was 8,700 with a normal differential count The urinalysis was negative

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* [illegible]

** [illegible]

Chest fluoroscopy and roentgenograms in the posteroanterior view showed the left hemithorax to be completely obscured by a homogeneous density which extended upward to the second anterior rib (Fig 1) The lateral view showed the area of increased density to be more marked in the anterior portion of the chest The posteroanterior roentgenogram showed the density to be less marked at the periphery than at the center Thoracentesis through the left seventh intercostal space in the anterior axillary line with a No 13 gauge needle yielded a small quantity of fatty tissue No fluid could be obtained

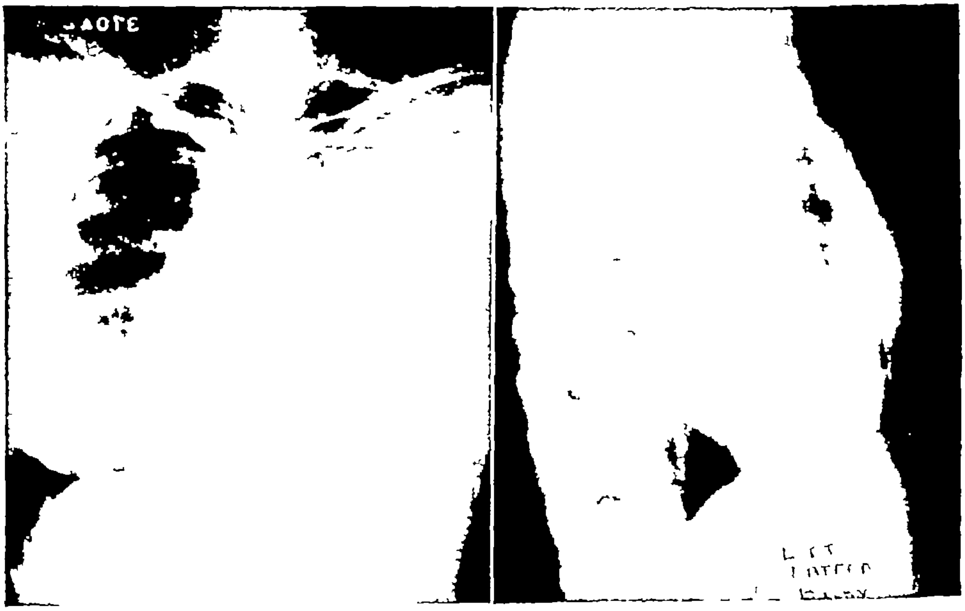
A *B*

Fig 1 — A and *B* Preoperative posteroanterior and left lateral chest films showing the large lipoma of the mediastinum protruding into the left chest

A presumptive diagnosis of lipoma of the left chest was made because of the long duration of symptoms, the characteristic x ray appearance (diminished density at the periphery of the mass), and the aspiration of fatty tissue by thoracentesis

Operation —On Sept 28, 1950, the operation was performed Anesthesia used was Pentothal Sodium induction, cyclopropane, ether administered via an endotracheal tube with assisted respirations * The patient was then placed in the lateral position on the right side The left pleural cavity was entered through the bed of the seventh rib, which was excised subperiosteally On opening the pleura an enormous fatty tumor was seen filling almost the entire left pleural cavity and pushing the mediastinum and heart into the right chest The mediastinal pleura covered the tumor which was attached to the anterior mediastinum by a broad pedicle The mediastinal pleura was opened and the tumor enucleated from the mediastinal sac

The tumor was supplied by one medium sized artery from the anterior mediastinum The redundant mediastinal pleura was excised and the defect partially closed, leaving an opening for drainage into the pleural cavity. Controlled respiration by the anesthesiologist was limited until the tumor was shelled out of the mediastinal sac. There was a drop in blood pressure at this point from 150/90 to 120/75. The pulse slowed from 100 to 90. There was no other perceptible change in the patient's condition. The left lung when completely expanded appeared to be normally formed in all respects except for its small size. The inflated lung occupied approximately 50 per cent of the left pleural space. There was no exudate over the visceral pleura to prevent complete expansion of the lung. Anterior and posterolateral tubes were inserted and attached to subaqueous drainage bottles before closing the chest.

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*Anesthesia was administered by Dr John Owen

[illegible]

of adipose tissue The histopathology sections showed the structure to be practically normal adipose tissue cells, and the diagnosis was large lipoma from left anterior mediastinum and left chest

Course—The postoperative course was uncomplicated except for delayed expansion of the left lung The intercostal catheters were removed in forty eight hours On October 6, thoracentesis was done with removal of 850 c c. of blood tinged fluid from the left chest, and three days later 900 c c of amber fluid was removed Thoracenteses were continued at weekly intervals for one month, with removal of about 500 c c. of amber fluid each time The patient was then followed with fluoroscopic examination for several weeks The fluid showed no increase beyond a certain point so thoracenteses were discontinued It was thought that the fluid was simply filling the space in the pleural cavity which the small lung could not fill

Subsequent films have shown gradual clearing of the left base The last film on March 23, 1953, two and one-half years since operation, shows the chest is essentially normal except for slight elevation of the left diaphragm (Fig 3) The patient at this time has no symptoms referable to the chest, except a feeling of slight "tightness" of the left lower chest There is no dyspnea or difficulty in swallowing

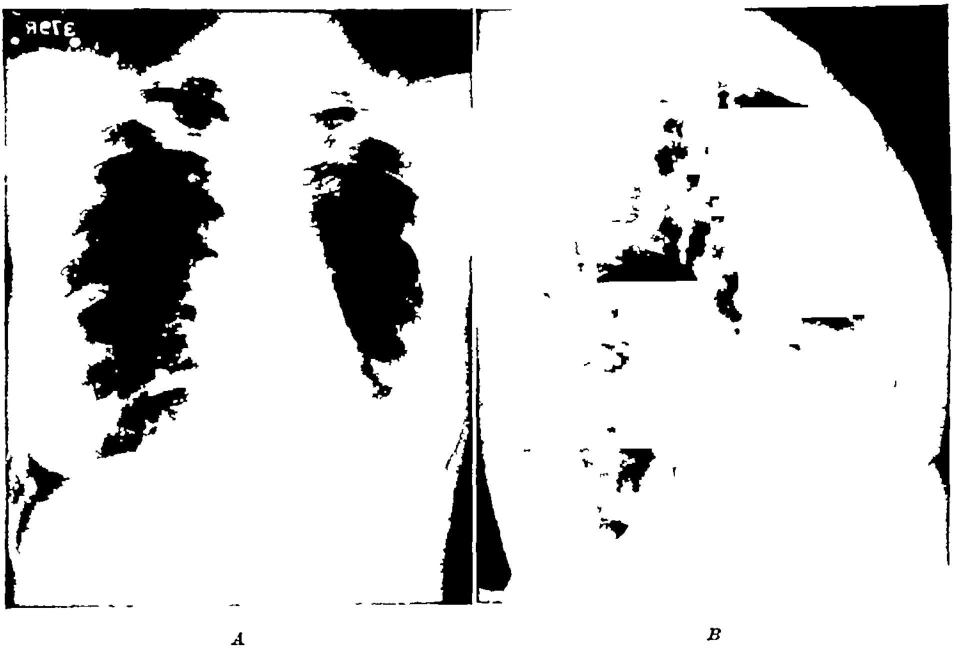

Fig 3—*A* and *B* Postoperative films taken two and one-half years after resection of the tumor

DISCUSSION

The relative infrequency of this tumor in the mediastinum has been emphasized by Blades,[5] who in 1941 reported only two cases of mediastinal lipoma had been seen at Barnes Hospital in St Louis and by Sabiston and Scott,[6] who in 1952 reported 101 primary tumors or cysts of the mediastinum observed at Johns Hopkins Hospital from 1933 to 1951 Only two lipomas were included in this series both originating in the posterior mediastinum The entirely intrathoracic tumors make up the largest group, forty one having been recorded at the time of Keeley's report The most common symptoms reported are those of exertional dyspnea and the feeling of oppression or heaviness in the chest. The benign nature of the process is suggested by the long duration of symptoms and the good general condition of the patient with the presence of a large intrathoracic mass. The diagnosis prior to operation has been made in only six cases prior to the present report and was based on aspiration of fat in four cases. Lipoma may be suspected when there is a relatively clear peripheral zone. This has been pointed out by Heuer to be due to the difference in specific gravity between fat and fluid.

The suggestion of Keeley and associates seems appropriate that intrathoracic lipomas be classified in two groups: those that are entirely intrathoracic and those that have intra- and extrathoracic portions. The latter group is more frequently discovered by the presence of the extrathoracic portion, whereas the intrathoracic types are usually discovered during routine x-ray examination of the chest, or because of the cardiorespiratory symptoms due to the location and size of the tumor.

It has been pointed out by several authors that there may be compensatory adjustments of the cardiorespiratory system due to the large space occupying mass. The sudden removal of the mass may produce serious cardiorespiratory problems.

The most common postoperative complication, as exemplified by the present case report, has been the accumulation of serosanguineous fluid. It seems plausible that the increased negative pressure in the pleural cavity after removal of the large mass with insufficient lung volume to fill the cavity is probably the most important factor in the production of the fluid.

SUMMARY

A report of the successful removal of an 8 pound 1 ounce mediastinal lipoma is presented. It is believed to be the largest intrathoracic lipoma successfully removed to this date.

This is the seventh intrathoracic lipoma which has been diagnosed prior to operation. Five of these, including the present case, were based on aspiration of fat.

The present case makes a total of fifty-nine cases of intrathoracic lipomas reported, of which thirty-one have been successfully removed.

USE OF THE THORACOSCOPE IN THE DIAGNOSIS OF CERTAIN INTRATHORACIC NEOPLASMS

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AT TIMES the physician is confronted with the problem presented by the case in which he feels certain malignant disease is present, but in which he is unable to establish a tissue diagnosis In some cases the criteria of inoperability, such as extensive spread or metastasis, are already present or would be if a definite histologic diagnosis could be made This is especially so in thoracic surgery, where often the diagnosis of malignancy can only be made at the time of open thoracotomy In many such cases bronchoscopy, bronchial washings, needle biopsies, and supraclavicular fat pad biopsies are of no avail, and if malignancy could be proved in some other way the patient could be spared the morbidity and expense of exploratory thoracotomy for an obviously inoperable lesion

In certain selected cases of intrathoracic malignancy, especially when pleural effusion is present, thoracoscopy with biopsy of suspicious pleural nodules or plaques may be of aid in establishing the histologic diagnosis Direct visualization of the pleural surface for pleural adhesions was introduced by Jacobaeus in 1922,[1] after ten years of experience with the method Chandler and Morlock[2] in 1938 first described the use of thoracoscopic biopsy in the diagnosis of various intrathoracic lesions Since then there have been only occasional remarks in the literature concerning this little used but sometimes very valuable adjunct to the surgeon's armanentarium[3-5] The procedure of thoracoscopy is simple to perform, tolerated well by the patient, and can be carried out in any center where a thoracoscope is present

TECHNIQUE

The instrument in use at this hospital is a standard Coryllos thoracoscope with two sheaths (Fig 1) The patient is placed in the supine position or with the affected side slightly elevated The procedure is carried out under local anesthesia, the thoracoscopic trocar and sheath being inserted through the most appropriate interspace

After entering the pleural cavity the trocar is removed from the sheath, and pneumothorax is thus established All fluid is removed from the pleural cavity by insertion of a small catheter through the sheath and the application of suction The telescope and light are then introduced and the pleural cavity inspected The diaphragm, visceral and mediastinal pleural surfaces can be well visualized, and adhesions, nodules, fluid, or other abnormalities can be easily seen and studied

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If suspicious nodules can be seen, especially on the diaphragmatic or mediastinal surfaces a second trocar and sheath are inserted through an adjacent interspace. Through the second sheath an appropriate forceps can be inserted and biopsies taken under direct vision. It has been our policy to biopsy areas of shaggy fibrinous exudate on the pleural surfaces even if these do not appear suspicious of tumor, and on several occasions nests of malignant tumor cells have thus been found. Direct biopsy of the intact and apparently normal visceral pleura is not advisable however, because of the possibility of perpetuating the pneumothorax.

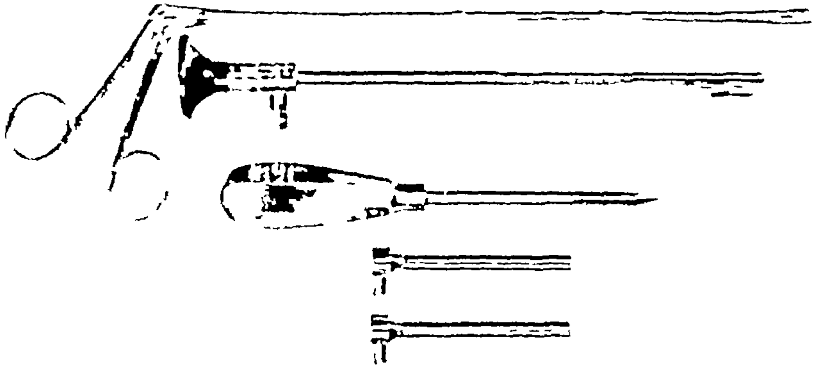

FIG. 1. The thoracoscope with double sheath and laryngeal biopsy forceps

Upon completion of the examination a small catheter is inserted into the pleural cavity through one of the trocars (usually the most superior one), and after the removal of the trocars the lung is re-expanded by suction through the catheter. After re-expansion of the lung the catheter is removed. If it is desired to maintain constant negative pressure for a more prolonged period a No. 18 Foley catheter may be inserted through the sheath instead, the bag of the catheter inflated and the catheter attached to an underwater seal drainage bottle. All of our cases have withstood the procedure without incident.

The left chest was clear There was palpable enlargement of the liver Chest x ray pictures taken on entry revealed massive pleural effusion on the right to the level of the third rib anteriorly In addition, there was a rounded density 2 cm in diameter visible in the right upper lung field, which was thought to be either a pulmonary tumor or loculated fluid. Bronchoscopy on Jan 18, 1952, revealed displacement of the coryna (tracheal carina) to the left, but no visible endobronchial neoplasm Microscopic study of the sediment from several thoracenteses revealed no abnormal cells On Jan 25, 1952, a right supraclavicular fat pad biopsy was done and one lymph node was obtained which was reported to show reactive hyperplasia

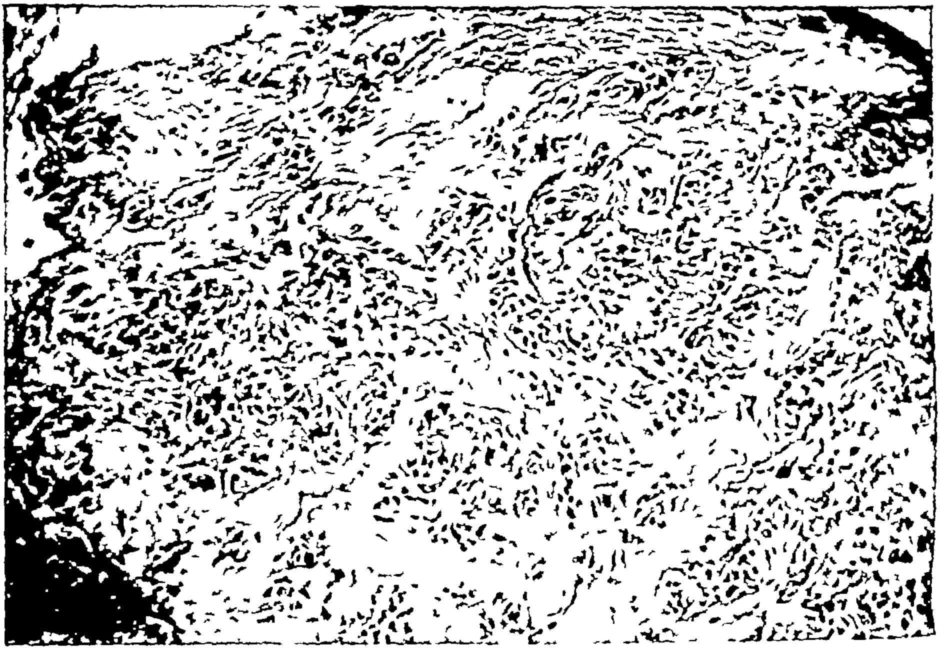

Fig 2—Photomicrograph (×115) from Case 1 demonstrating nests of malignant cells in a pleural plaque This is representative of the biopsies obtained in the other reported cases

On Feb 1 1952 thoracoscopy was performed under local anesthesia, and numerous small nodules were seen on the anteromedial surface of the lung and on the lower parietal pleura Biopsies taken through a second sheath demonstrated "carcinoma of parietal pleura" (Fig 2) The patient was considered to have inoperable carcinoma of the lung, was given appropriate supportive care, gradually "went downhill," and expired on March 27, 1952 Autopsy was not permitted

Case 2—F E B, No 49253 This 58 year old man entered San Francisco Veterans Administration Hospital on Feb 17 1952 because of increasing dyspnea, cough and malaise of six months duration He had lost five pounds of weight in the three weeks prior to entry Examination on entry revealed diminished expansion of the left chest, flatness to percussion, and decreased breath sounds and tactile fremitus over the entire left chest The cardiac border was not discernible Chest x ray films revealed a massive left pleural effusion Culture of pleural fluid on entry was positive for pneumococci Repeated thoracenteses were done between February 18 and March 5, all yielding about 1,000 c c of serosanguineous fluid Chest x ray pictures taken at all times revealed only massive pleural effusion Cytologic studies on the pleural fluid were inconclusive Bronchoscopy undertaken on March 7, 1952 revealed edema and narrowing of the orifices of the left upper and lower lobe bronchi but no intrinsic tumor

was a left Horner syndrome Dullness to percussion was noted on the left chest below the first anterior interspace The trachea was deviated slightly to the left A left thoracentesis on July 29, 1952, yielded 700 c c of serosanguineous fluid No malignant or suspicious cells were detected in the thoracentesis fluid

The patient underwent thoracoscopy on Aug 1, 1952, at which time it was noted that the pleural surfaces were covered with a shaggy grayish exudate, but no actual tumor nodules were made out Through a second sheath multiple biopsies of the exudate were taken The pathologists' report on the biopsies was ''undifferentiated carcinoma '' On Aug 2, 1952, the patient had a bout of severe cyanosis and dyspnea from which he spontaneously recovered He had another bout of cyanosis and dyspnea on Aug 4, 1952, and expired suddenly Autopsy revealed carcinoma of the left lung with pleural, hepatic, splenic, renal, cardiac, and rib metastases The immediate cause of death was a right pulmonary embolism

COMMENT

Frequently the diagnostic procedures of bronchoscopy, bronchial washings, needle biopsy, and supraclavicular fat pad biopsy are of no avail in the diagnosis of intrathoracic malignancy Under these circumstances, thoracoscopy may be of great help in establishing a diagnosis

Thoracoscopic biopsy is a procedure, the value of which may not be realized by many general and thoracic surgeons In certain selected cases it may provide a proved diagnosis and at the same time establish inoperability of a lesion, and save the patient the morbidity and expense of exploratory thoracotomy

It is to be emphasized that the procedure is not recommended in cases in which an apparently operable lesion is present, because of the possibility of contamination of the pleural cavity with tumor cells The procedure may be indicated in certain cases of intrathoracic extrapulmonary tumor, pulmonary malignancy with signs of pleural spread, metastatic tumors, and lymphomas with effusion The technique is simple The procedure is well tolerated by the patient and can be carried out by any surgeon with a moderate amount of thoracic surgical experience Most medical centers, especially those treating tuberculosis, possess the required instrument

SUMMARY

The indications for thoracoscopy with biopsy and its technique are briefly discussed The simplicity of the procedure is emphasized Experience with five consecutive cases of obscure pulmonary disease in which thoracoscopy with biopsy was done is cited In all of these cases an accurate histologic diagnosis was made

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HIATUS HERNIA THE PROBLEM OF DIAGNOSIS

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DIAGNOSIS of hiatus hernia has for years been the responsibility of the radiologist. The clinical impression which could not be substantiated roentgenologically has not ordinarily been considered adequate to justify surgical exploration for confirmation and repair. Diagnosis based on the history and physical examination has been discouraging when the roentgen method has been used as the diagnostic base line. Gastroscopic and esophagoscopic examinations have frequently been made in a search for the complications of hiatus hernia and the results have raised certain questions about the diagnosis of the basic disease. The present report deals with diagnostic experiences among a group of patients proved by radiologic or endoscopic means to have a hiatus hernia.

MATERIAL AND METHODS

Among adult patients studied because of upper abdominal and chest complaints during the past three years the diagnosis of hiatus hernia has been made by combined roentgenologic and endoscopic techniques eighty two times. All hernias were of the direct or common type with simple transhiatal displacement of cardia and varying amounts of stomach. In twenty one instances the esophagus was judged to be permanently shortened, the other hernias showing [illegible]. Eleven of the patients were women.

The roentgenologic studies were made by several radiologists always with the request to search for diaphragmatic hernia. The esophagoscopic and gastroscopic examinations were made by one observer who in each instance was aware of the findings of at least one recent roentgenologic examination. The Eder-Hufford esophagoscope which is fitted with a swinging telescope furnishing [illegible] magnification was used.

In [illegible] patients brain clips were fastened to the esophagogastric junction [illegible] gastroscopic biopsy by a technique previously described[1]

RESULTS

TABLE I CASES OF PROVED HIATUS HERNIA. DIAGNOSTIC RESULTS OF THREE EXAMINATION METHODS

	X RAY	ESOPHAGOSCOPY	GASTROSCOPY
No patients examined	82	51	41
No patients with positive examination	64	44	19
Total no examinations made	159	68	56
No positive examinations	76	57	20
First examination positive no patients	49	41	16

those instances in which the radiologist had already detected the hernia, the endoscopist approached his examination forewarned Of the sixty eight esophagoscopic examinations 84 per cent were positive

Gastroscopy was the least efficient diagnostic method Forty-one patients were examined The diagnosis was made in 46 per cent The first examination was positive in 39 per cent

If the roentgenologic method alone had been relied upon, the diagnosis would have been overlooked in 40 per cent (of eighty-two patients) Esophagoscopy alone would have failed in 20 per cent (of fifty one patients), and gastroscopy in 61 per cent (of forty-one patients)

TABLE II ESOPHAGEAL COMPLICATIONS DIAGNOSTIC FINDINGS AMONG 51 PATIENTS STUDIED *BY X RAY EXAMINATION AND ESOPHAGOSCOPY*

	TOTAL NO DIAGNOSED	NO DIAGNOSED BY X RAY	NO DIAGNOSED BY ESOPHAGOSCOPY
Esophagitis	7	0	7
Stricture	2	2	2
Ulcer	3	1	3
Diverticulum	3	3	0

Diagnosis of the esophageal complications of hiatus hernia (Table II) clearly required both radiologic and esophagoscopic study The seven instances of esophagitis discovered by endoscopic means were not detected roentgenologically, *and only the latter method demonstrated the three cases of esophageal* diverticulosis Two of three esophageal ulcers were found only by esophagoscopic examination The two strictures were easily diagnosed by both methods

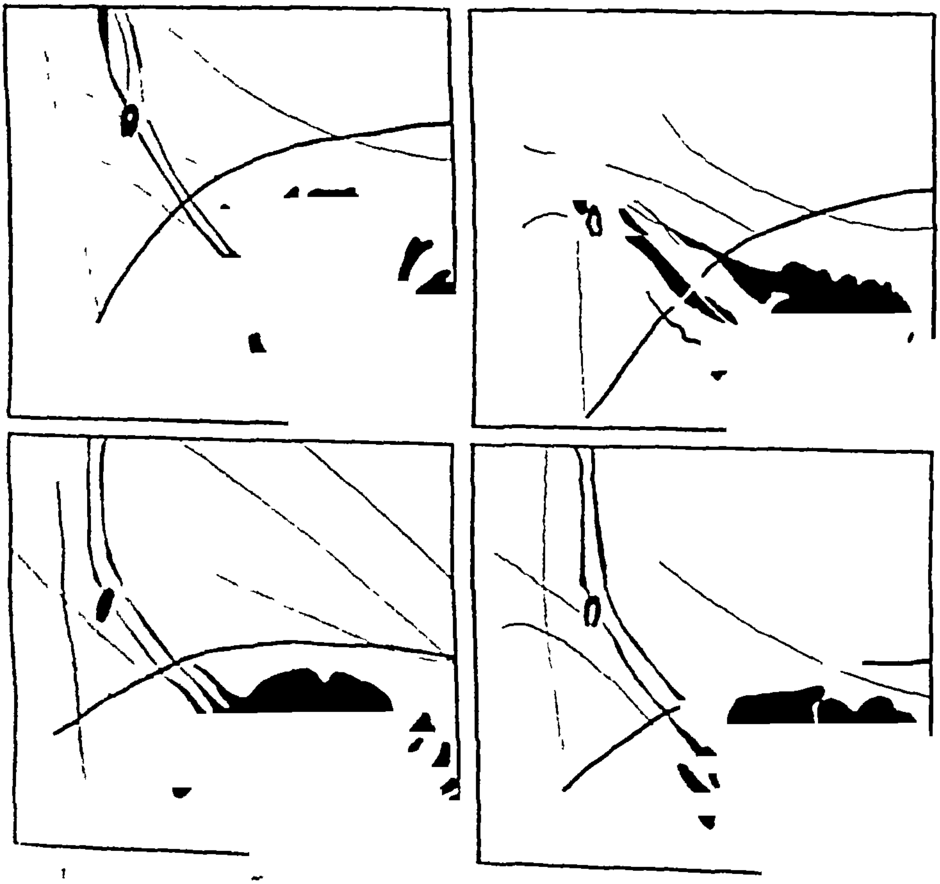
Gastroscopy proved more helpful than roentgenography in the diagnosis of secondary changes within the herniated portion of the stomach (Table III)

TABLE III GASTRIC COMPLICATIONS DIAGNOSTIC FINDINGS AMONG 41 PATIENTS STUDIED BY X RAY EXAMINATION AND GASTROSCOPY

	TOTAL NO DIAGNOSED	NO DIAGNOSED BY X RAY	NO DIAGNOSED BY GASTROSCOPY
Erosive gastritis	10	0	10
Ulcer in hernia	2	0	2
Elsewhere	8	8	6

Parenthetically it may be mentioned that among these eighty two patients the clinical studies, as dictated by the individual clinical problems presented demonstrated nine instances of Saint's triad[2] (hiatus hernia gallstones and diverticulosis coli)

In eight patients radiologic esophagoscopic disagreement aroused particular local controversy, and therefore, transesophagoscopic biopsies were taken at the esophagogastric junction and brain clips fastened to the biopsy sites for roentgenologic reference. Five of the biopsy specimens showed only gastric mucosa, one esophageal, and two mucosa from the esophagogastric junction itself. In all instances later fluoroscopic study revealed the clips lying superior to the hiatus. The radiologist was then able to demonstrate a hernia in four patients. Two of these were treated medically. The other two were operated upon, the hernia demonstrated and the hiatus repaired.



[illegible] clip revealed [illegible] mucosal pat[illegible]

[illegible]

At thoracotomy a hiatus hernia extending about 4 cm above the diaphragm was found and repaired

CASE 2.—A 22 year old white soldier had complained of daily nausea, epigastric burning, and gas for two years. There was moderate aggravation upon recumbency. Five roentgenologic examinations, with particular reference to the cardia, failed to reveal a diaphragmatic hernia.

Four esophagoscopic examinations were made. A hiatus hernia was found at each, and it was estimated that the esophagogastric junction lay 4 cm proximal to the hiatus. Biopsies were taken below the junction on two occasions, and both specimens were found to be of gastric mucosa. Clips were placed at the biopsy site the second time, and roentgenologic examination showed the clips to lie about 6 cm above the hiatus, but no hernia could be demonstrated (Fig. 2).

At thoracotomy the diameter of the hiatus was found to be about twice normal. Six linear centimeters of the stomach extended above the diaphragm. The defect was repaired.

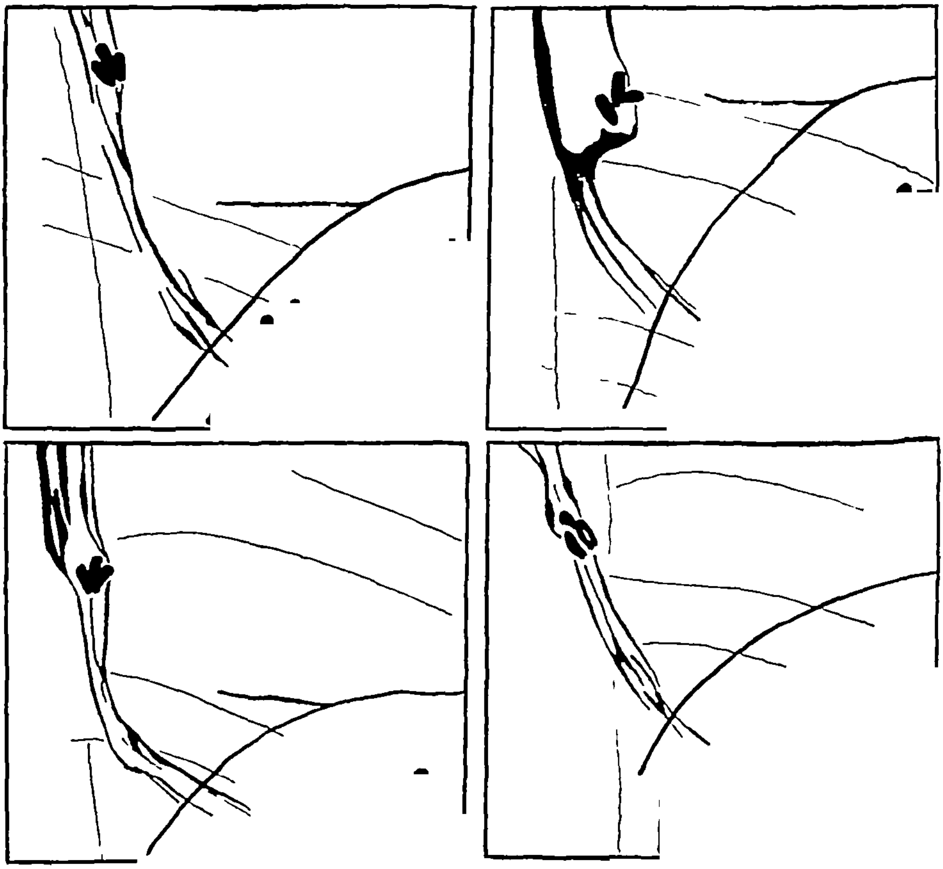


Fig. 2.—(Case 2.) Tracings of spot films as in Fig. 1. Biopsy taken at site of the three clips was of gastric mucosa. The mucosal pattern below the clips seems to be esophageal. Abnormality could not be demonstrated roentgenologically. A 6 cm. hiatus hernia was found at thoracotomy.

COMMENT

The propensity of some hiatus hernias to undergo spontaneous and rapid reduction is only one of the factors hindering diagnosis. The radiologist is not able to detect the junction between esophageal and gastric mucosa and *must* renders his opinion on the basis of the number and configuration of the regional mucosal folds plus the point of sudden increase in the tube's diameter. To the esophagoscopist mucosal appearance is paramount, and with the help of telescopic magnification the line marking the esophagogastric mucosal junction is easily recognized in most cases. The number and configuration of regional folds are rapidly changing endoscopic features and to the esophagoscopist are not particularly useful for differentiation of the two organs. Similarly, true variations in lumen diameter are often difficult to recognize.

The esophagoscopist and radiologist then depend on quite different anatomic features for the diagnosis of hiatus hernia. In order to evaluate the diagnostic problem it is necessary to determine the relationship of the line of the esophagogastric junction to the point at which the digestive tube's lumen suddenly widens. This latter feature has been viewed classically as marking the end of the esophagus and beginning of the stomach. However, regardless of gross configurations, any part of the digestive tract which is covered by gastric mucosa contiguous with the mucosa of the stomach as classically defined can be considered stomach. The nature of the mucosa makes the difference because, as Barrett has emphasized, any segment covered by gastric mucosa functions physiologically as stomach and falls heir to the diseases of the stomach.

In a previous study[4] it was found that part of the normal resting "abdominal esophagus" is lined by gastric mucosa which may extend as far as 3 cm. upward into the esophagus. Furthermore, the mucosa of the esophagogastric junction region is capable of automatic rhythmic migration between diaphragmatic hiatus and brink of gastric cavity, possibly through the action [illegible] cers upon occasion shows gastric mucosa, and, consequently, it has been suggested from time to time that aberrant islands of gastric mucosa may play an important role as locus minoris resistentiae for peptic ulcer of the esophagus This is not the time to discuss aberrant gastric mucosa, but it is interesting to speculate upon possible misinterpretation of contiguous mucosal extensions for isolated islands

The present study indicated clearly that the esophagoscopic method is able to bring to light a significant number of clinically important, surgically demonstrable hiatus hernias which cannot be recognized upon repeated radiologic study Use of the biopsy and brain-clip technique has been most instructive in proving the point

SUMMARY AND CONCLUSIONS

Eighty-two adults with hiatus hernia were studied roentgenologically and endoscopically The diagnosis was made by repeated roentgenologic examination in 78 per cent, the first examination demonstrated the defect in 60 per cent Of those examined esophagoscopically the diagnosis was made in 86 per cent, 80 per cent upon the first examination Gastroscopic study revealed the hiatus hernia in 46 per cent of those examined, 39 per cent upon the first examination

All of the examination methods proved indispensable for demonstration of the esophageal and gastric complications of hiatus hernia

Study of eight patients by means of transesophagoscopic biopsy and attachment of brain clips showed that the roentgenologic method was not effective in distinguishing the mucosal pattern of the esophagus from that of the stomach It is believed on the basis of previous studies that the gastric mucosa usually extends upward into the normal resting "abdominal esophagus" and that the mucosa of the esophagogastric junction may migrate rhythmically from the level of the diaphragmatic hiatus to the brink of the gastric cavity Some implications in regard to hiatus hernia are discussed

Appreciation is expressed to Colonel Sanford W French Medical Corps, United States Army and to Lieutenant Colonel John S Paul, Medical Corps, United States Army for the accomplishment of the thoracic surgery described

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CIRCULATORY STATUS OF RESECTED TUBERCULOUS PULMONARY LOBES

RAYMOND J BARRETT MD (BY INVITATION), MIKIO MASAKI MD (BY INVITATION) AND J C DAY MD
DETROIT MICH

OBSERVATIONS have been recorded concerning the vascular supply of the lung since the time of Galen who is said to have been the first to recognize the double supply of that organ William Snow Miller's[1] classic monograph on the subject summarized the observations of numerous eighteenth and nineteenth century anatomists and contributed much that still remains the basis for our present knowledge It is well known that the pulmonary arteries are end arteries Normally there is no precapillary communication between the pulmonary artery and the bronchial arteries Communication between these two systems is said to occur only by means of a capillary bed in the walls of the respiratory bronchioles How much of the blood from the bronchial arteries if any normally reaches the walls of the alveoli themselves is not known

In chronic diseases of the lung changes are known to occur in both of the vascular systems In 1929 Kaufmann[2] described the obliterative changes in the pulmonary artery in tuberculosis and in 1933 Coryllos speculated on the probable beneficial effect of the changes on the disease Obliterative endarteritis is a characteristic feature of pulmonary tuberculosis This was well demonstrated by [illegible] and Prosmus[4] in 1938 They injected the pulmonary arterial circulation of tuberculous lungs obtained at autopsy Their conclusions were that pulmonary tuberculosis causes a marked decrease in pulmonary arterial [illegible] in the portions of the lung involved and that the impairment was [illegible] to the degree and stage of the involvement They also emphasized [illegible] cers upon occasion shows gastric mucosa, and, consequently, it has been suggested from time to time that aberrant islands of gastric mucosa may play an important role as locus minoris resistentiae for peptic ulcer of the esophagus. This is not the time to discuss aberrant gastric mucosa, but it is interesting to speculate upon possible misinterpretation of contiguous mucosal extensions for isolated islands.

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All of the examination methods proved indispensable for demonstration of the esophageal and gastric complications of hiatus hernia.

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DETROIT, MICH.

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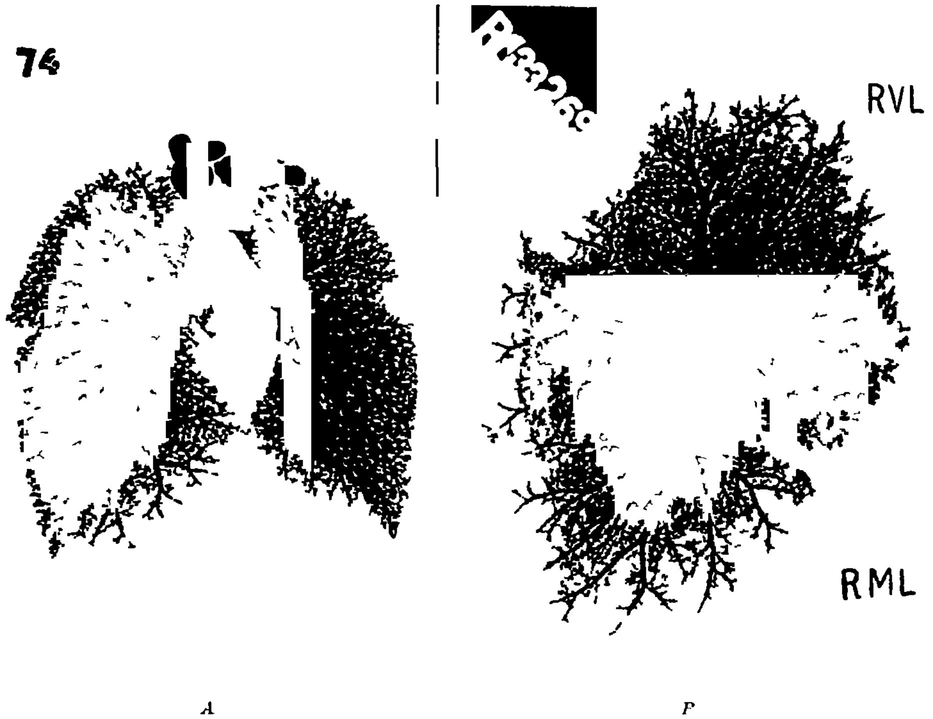
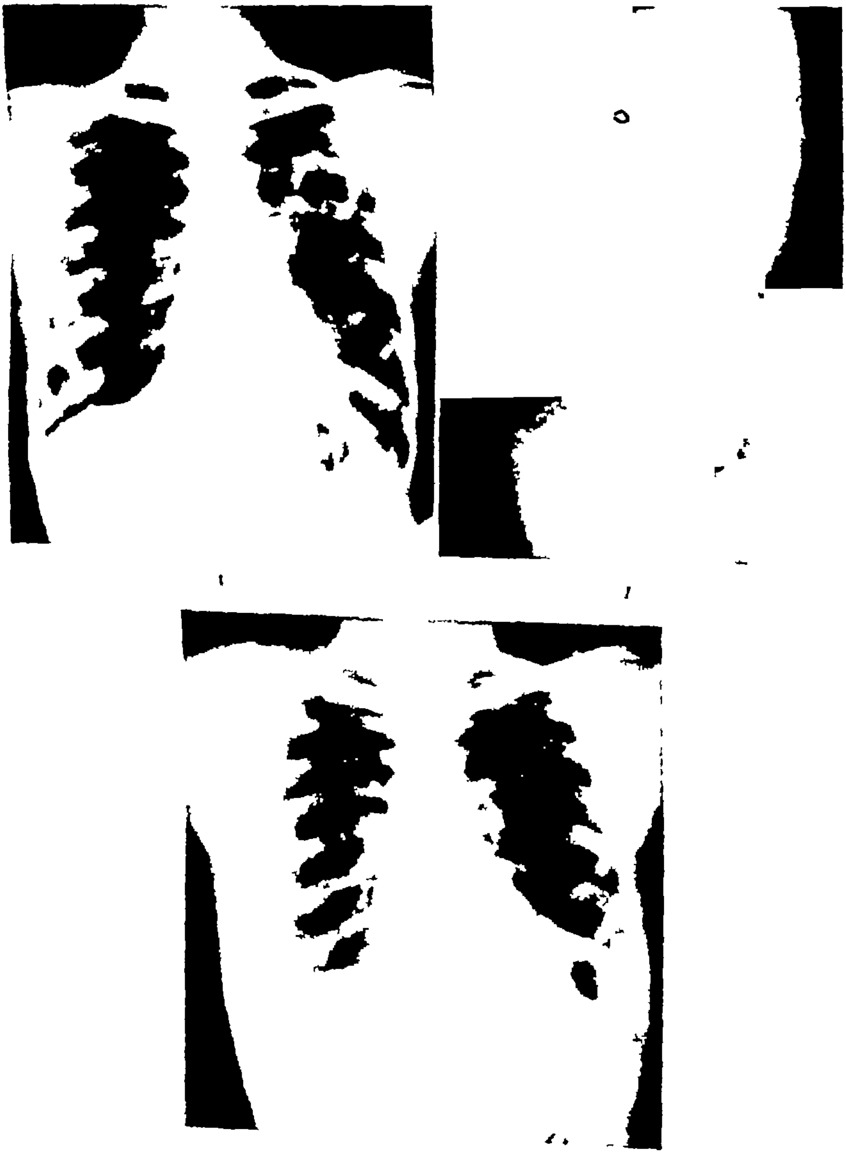


Fig 1 —*A* Injection of normal pair of lungs from a child Note the uniform filling and graduated decrease in caliber from major vessels to arterioles and precapillary twigs. *B*, Injection of normal right upper and middle lobes from an autopsy on an adult who died of meningitis There is some emphysema present, particularly in the apex of the upper lobe where blebs are seen

Fig 2 —*A* X ray picture of an uninjected specimen The entire left lung is involved in exudative disease while there is also a band of exudative disease in the upper right lung field There is scattered productive disease throughout the remainder of the lung field *B* Injection of the specimen in *A* reveals a destroyed circulation in the areas of exudative disease The vessels are straight, thin, and stripped of their end arteries A similar involvement has taken place in the area of exudative involvement on the right

diffusion of gases is rather remote and for all practical purposes it can be disregarded. For the purpose of this paper we shall exclude entirely the bronchial arterial component.

In the present resection era in the therapy of tuberculosis the previously mentioned anatomic changes assume practical importance. There is considerable enthusiasm today for segmental and subsegmental resections for residual caseous foci remaining after long-term antibiotic therapy. It occurred to us that in



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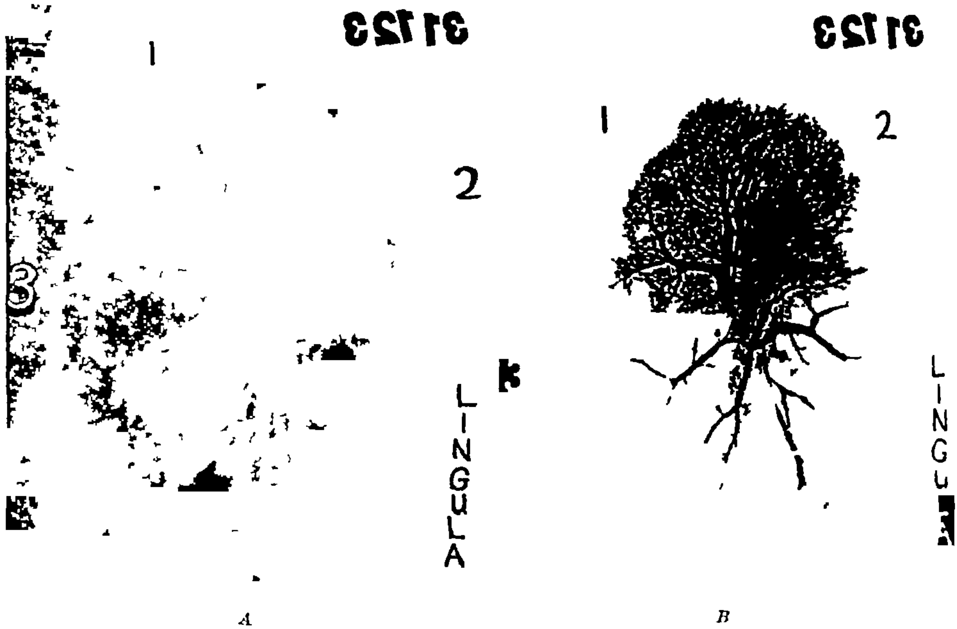
the extensively involved lobe which had shown rather striking x-ray regression after therapy, it might be expected to find significant impairment of the vascular pattern throughout the lobe and not only limited to the areas of residual x-ray lesions If this hypothesis were to prove correct then its implications regarding the functional capacity of the lung would be clear, and lobectomy, rather than segmental or subsegmental resection, would be indicated despite considerable improvement on serial x-ray films If such a status did not obtain with any degree of consistency then the indication should be clear for limiting the resection to the segments or subsegments containing the residual lesion evident in the x-ray picture



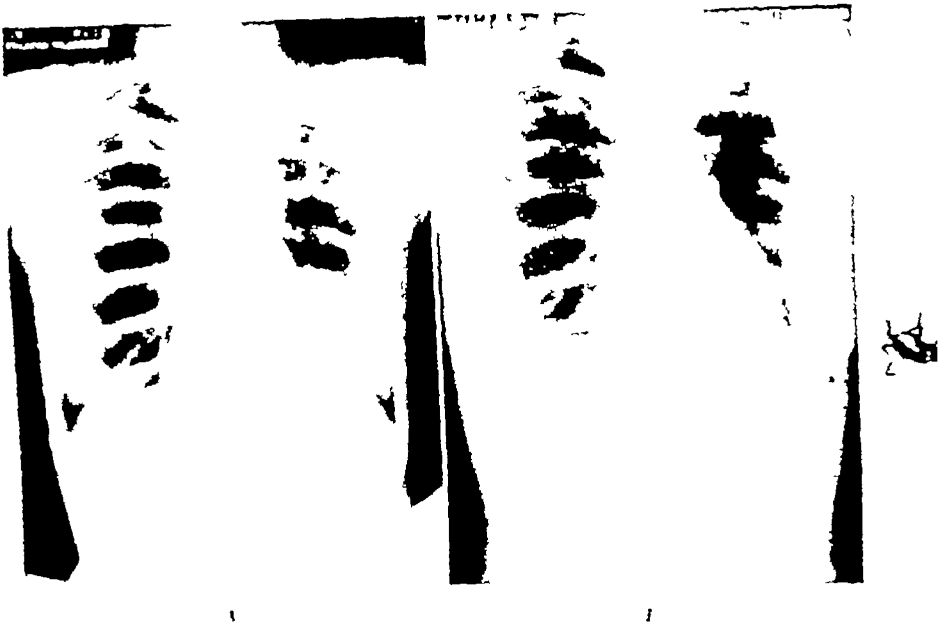
A *B*

Fig 4 —4 This is a roentgenogram of the uninjected resected specimen from Fig 3 The segments are numbered according to the Jackson Huber classification Notice that only the apical segment is uninvolved *B* This is a roentgenogram of the injected specimen The apical segment has a normal circulation as is the case with uninvolved segments this apical segment has overexpanded and at first glance would appear to represent a considerable amount of functioning lung tissue In actuality an overdistended normally vascularized segment will be less efficient than a similar segment of normal volume The posterior segment shows long thin trunks crowded n branching and end arteries The underlying luminosities are due to the areas are seen in the tip of the lingula In the anterior segment which cavity the vessels fail to inject and lack branches The lingular vessels are similarly involved It is apparent that the vascular changes are more consistent with the parenchymal involvement at the height of the disease than that at the time of surgery

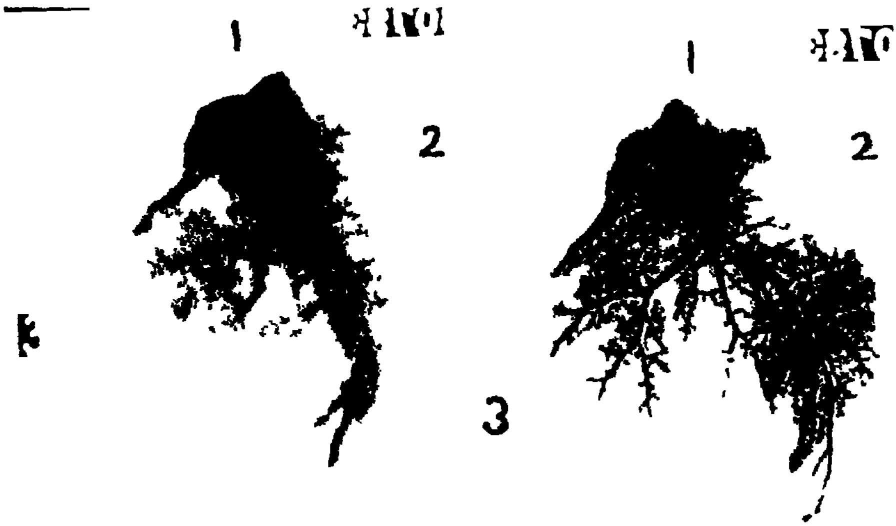
CLINICAL MATERIAL

In the course of this study, thirty-five resected lobes have been studied by means of roentgen visualization of the Lipiodol injected pulmonary arteries The individual arteries were injected with Lipiodol under a pressure of 25 mm Hg after the lobe had been inflated with air to a pressure of 4 to 6 cm of water

In some of the specimens the lung could not be inflated to its normal size because of pleural tears resulting from difficult dissections Many of the specimens were rejected because of technical errors in the injection, and others were



[illegible] After thirteen months of therapy the infiltrations in the apicoposterior and lin- [illegible] Three months later it reopened. B, Post[illegible] left upper lobectomy.



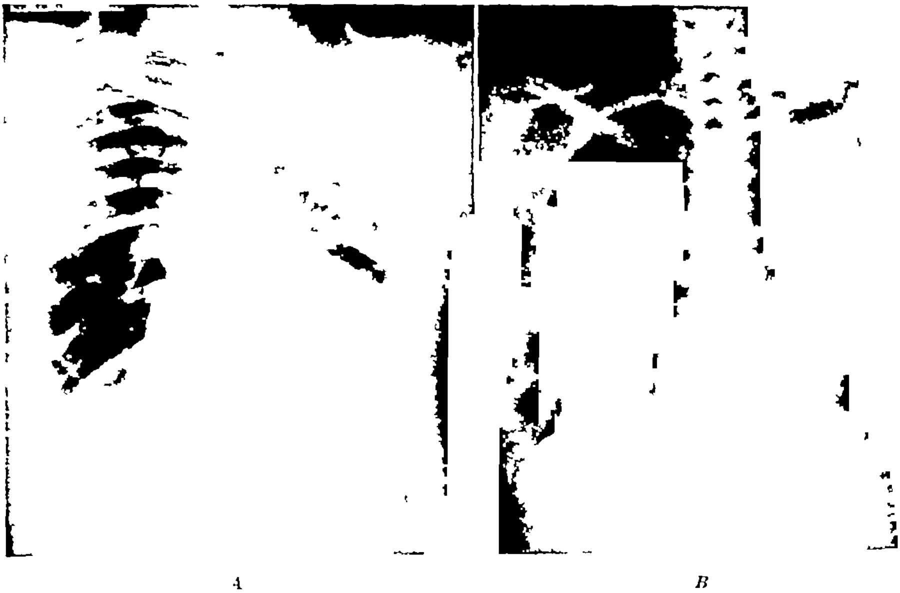


Fig 7 —*A* and *B* Here there is diffuse involvement of the left upper lobe which after twenty three months of therapy has cleared to an apical cavity

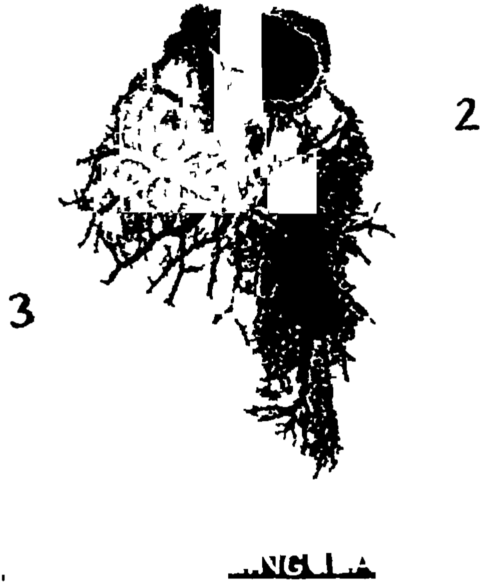
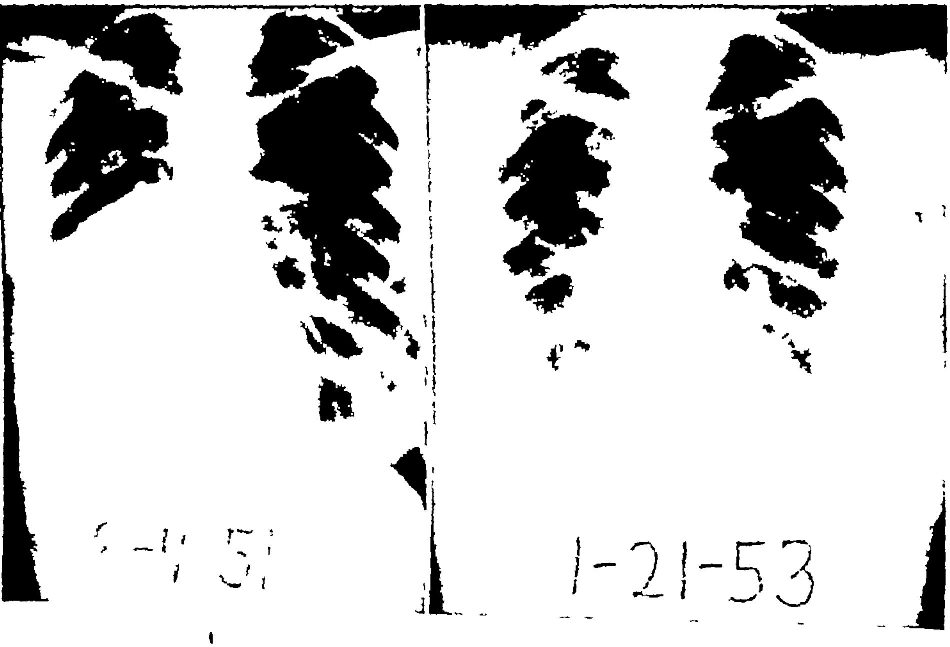


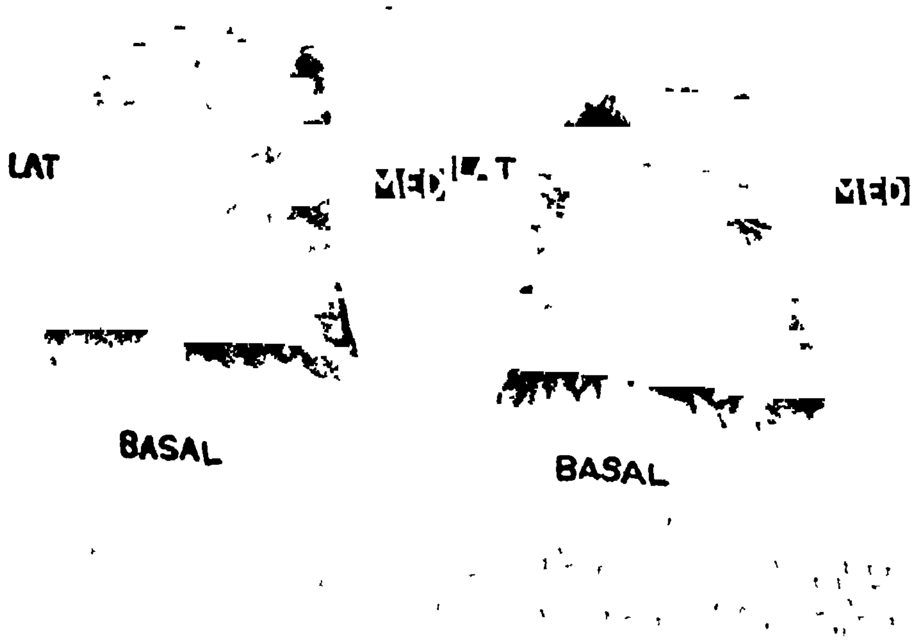
Fig 8 —Roentgenogram of the injected specimen taken from the lung shown in roentgenograms in Fig 7 reveals an overexpanded anterior segment with a relatively normal circulation. The apical segmental circulation is destroyed since the patient never had hemoptysis the vessel must have ruptured into the cavity during the course of the injection The vessels of the posterior segment are thin and straight and show decreased branching The lingular circulation is relatively abnormal throughout.

[illegible] permanent since there was sufficiently extensive x-ray involvement at the time of surgery to account for the destroyed vascular pattern which was found



A B

[illegible] the height of di[illegible] ntially the same picture per [illegible] which there [illegible] is gradual subsidence to the picture seen in B [illegible] months later and immediately prior to surgery. Only residual [illegible] of the lower lobe are seen. Because of palpable [illegible] was resected. This lower lobe is shown in



Fourteen satisfied the original criteria of extensive disease, clearing to relatively insignificant residuals Four of these cases comprise the present report

DISCUSSION

It is well accepted that pulmonary tuberculosis causes obliterative endarteritis There is considerable evidence to suggest that these changes are permanent Present-day concepts of resection predicate long-term preparation with antibiotics prior to resection of residual caseous foci It is apparent that any attempt to reconcile these facts reveals a basic discrepancy If an entire lobe has been involved with disease, arterial impairment of the entire lobe despite marked parenchymal clearing prior to resection might be expected

Operations designed to remove only the residual caseous foci may eliminate potentially dangerous areas of disease, but they are not necessarily function sparing since poorly vascularized lung remains which is capable of only minimal or negligible gaseous exchange Conversely, the retention of such nonfunctioning segments does prevent overdistention of the remaining uninvolved lobes and through a space-filling function it does tend to preserve all available normal parenchyma at optimal volume

When function testing becomes a practicable procedure for the smaller pulmonary units the way will be prepared for the ultimate solution of this problem

SUMMARY

1 An attempt has been made to investigate the permanency of endarterial changes in cases of pulmonary tuberculosis which have shown considerable regression under streptomycin therapy

2 In the main, those segments which were involved with disease will show impairment of their circulation despite later clearing of the parenchymal infiltration A gross exception to this in a case of lower lobe disease has been presented also

3 By implication some skepticism is expressed regarding the function sparing merits of segmental resection in originally extensively involved lobes

4 The ultimate solution to this problem must await arrival of a satisfactory method for direct function testing of individual pulmonary lobes and their segments

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EXTRAMUCOUS CLOSURE OF THE BRONCHIAL STUMP WITH CLIPS

An Experimental Study

Alejandro Pego Busto, M.D.,* Madrid, Spain, and E. S. Bucherl, M.D.,**
Gottingen, Germany

PROCEDURES for closing the bronchial stump have been described to such an extent that it can nearly be said that each thoracic surgeon with experience and inventive spirit possesses his own technique. For that reason we omit mentioning the various methods used, already known by all, and we are going to limit ourselves to presenting our original method.

Up to the present time the procedures employed have made use of various materials (silk, linen, nylon, steel, etc.) which cross the whole bronchial wall and which, fortunately in a very small percentage, produce intrabronchial intolerance signs with production of granulomas, irritative cough, etc. Such complications necessitate the extraction of this material bronchoscopically or sometimes the patient spontaneously expels it by coughing. This situation made us think that by using special clips which would not cross the mucosa, these complications would be avoided, producing a perfect *extramucous closure* of the stump. It could be considered as a useful method in human surgery, because it avoids mistakes which those methods described up to the present do not [illegible] at least theoretically it would be more ideal.

Intravenous sodium Evipan was used as the anesthesia, the optimum dose was 50 mg. per kilogram of body weight. After injecting curare in most of the dogs, intratracheal intubation was performed connecting the tube with an automatic respirator, oxygen was administered during the operation and rarely nitrous oxide was used as complement.

The dog was placed in lateral decubitus, we entered the pleural cavity through the fifth left interspace, injecting 1 to 2 c.c. of 1 per cent procaine intrapericardially before the ligature of the pulmonary artery. The pulmonary artery and the veins of the three lobes were dissected and ligated independently, the vagus nerve was dissected and separated so that it would not be injured or crushed with the clips as occurred with Dog 5.

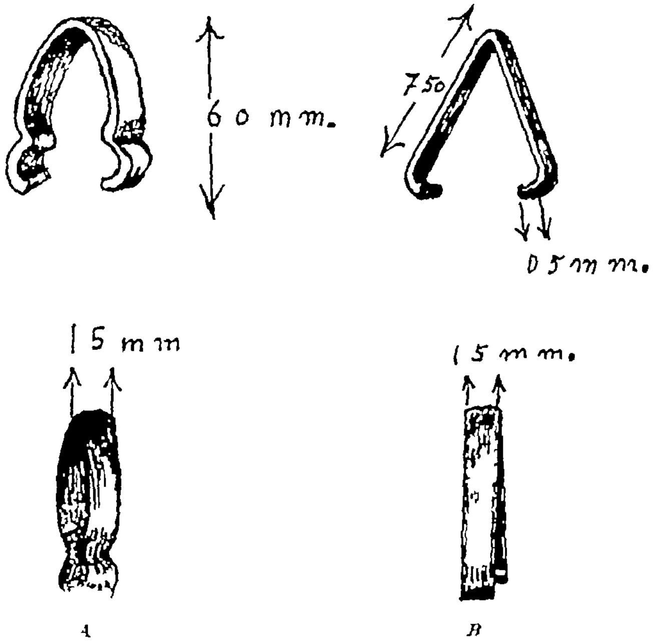
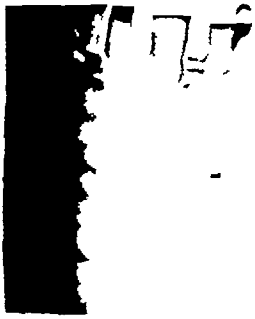
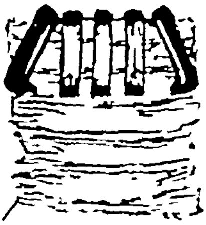


Fig. 1.—*A*, Shape and measurements of the silver clips. *B*, Shape and measurements of the V2A steel clips.

Two stitches of silk were put in opposite points of the bronchial wall to support the stump when the lung had been extirpated, in order to facilitate the placing of the clips. The bronchial stump was eventually closed by a T clamp so that the contralateral lung ventilation would not be disturbed; a clamp was shifted lengthwise as the clips are placed in position. Then the clips were perpendicularly placed on the edge of the bronchial stump (that is to say parallel to the longitudinal axis of the bronchial stump) except the two clips at the corners which we placed obliquely either *from the outside inward* or *from the inside outward*, as shown in Fig. 2, in order to close the angles completely to avoid the danger which really exists that the clips might slip outward as we observed in some instances when they were placed perpendicularly; we think this detail is important.

After placing the clips (generally four or five were quite sufficient), we acquired a good stump closure; this was proved by the disappearance of the noise produced by the suction of air. Only in Dogs 1 and 3 did we place a free pleural flap obtained from the resected lung, positioning it directly over the stump and on top of the clips. In the rest of the dogs we did not use a pleural flap; neither was the mediastinal tissue sutured nor approximated to the bronchial stump, which was spontaneously buried in its depth. The closure of the chest wall was by layers with catgut, at no time during the operation or the postoperative course did we use sulfonamides or antibiotics. In no case was drainage left nor was the phrenic nerve cut, except in Dog 1. A few days after the operation we obtained radiographs to determine the position of the clips (Fig. 3).





and the tolerance of the clips during a period of time varying from four days (Dog 3) to six months (Dog 10).

Dogs 1, 4, 6, and 9 are of no interest because their deaths occurred soon after the operation. The clips in these dogs were still in the positions where they were placed during the operation.

In Dog 5 it was necessary to place a skin clip in the superior end of the stump because of difficulties which arose in the placing of the V2A steel clips due to their hardness. At the necropsy a bronchopleural fistula was observed at the site of the skin clip, the rest of the stump was healed in spite of the fact that a branch of a V2A clip was displaced.

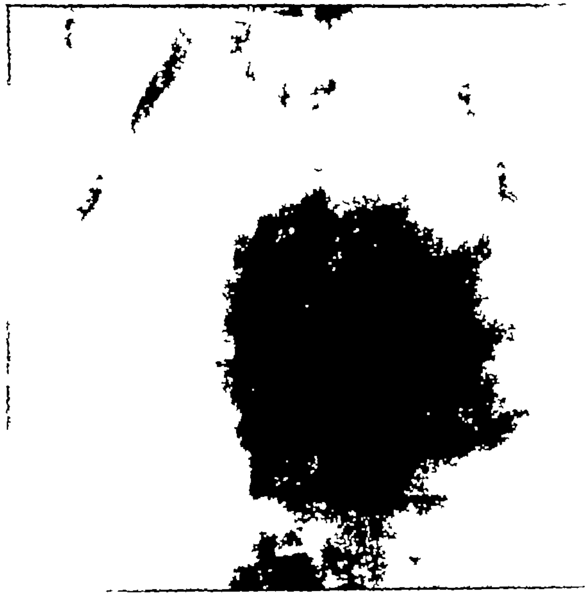


Fig. 3.—Position of the silver clips radiographically observed a few days after the operation. The upper clips are not displaced. Their appearance of displacement is due to the curve of the section of the bronchial stump.

The commentary on Dog 3 is very interesting. Upper and middle bilobectomy was performed and the bronchial stump was closed by placing a free pleural flap, obtained from the upper lobe, over it and on top of the clips immediately. At the autopsy, atelectasis of the lower lobe was observed, about 200 c.c. of sanguineous liquid was present in this pleural cavity, the pleural flap was necrotic and the stump, observed intrabronchially, had a perfect extramucous closure but without early signs of healing at the edge, which indicates that the necrotic flap hindered the normal healing process.

Dogs 2 and 7, which had no pleural flap or covering of mediastinal tissue, as the others did, were sacrificed the fifteenth postoperative day. The healing of the stump and mediastinal wound was observed and appeared to be completely normal although in both dogs, two and one clips, respectively, were intrabronchially displaced.

In Dog [illegible], which died on the seventh day because of an abscess in the chest wall, the healing was good, weak on half of one side, with two displaced clips.

In the rest of the dogs the stump healing was good, with a good extramucous closure, except in Dog 11, in which the teeth of a silver clip formed a intrabronchial prominence. Dog 13, sacrificed the one hundred sixty-eighth postoperative day, and Dog 10, sacrificed six months postoperatively, presented good closure with the clips in good position; there was normal healing, without inflammatory signs or intolerance, which was not microscopically controlled.

COMMENT

The extramucous closure method described complies with the conditions needed to guarantee the obliteration of the bronchial stump, its airtight closure as proved by the disappearance of the noise produced by the suction of air due to the coaptation of the stump edges. Since the clips are placed parallel to the direction of the vessels there is no interference with the bronchial blood supply; we must have respect for the conservation of the peribronchial tissue which is important in the healing process. There is also no interference with the areolar mediastinal tissue since there is enough space left between the clips. The clips have been well tolerated as demonstrated by the [illegible] six months after the operation that a good healing of the stump had [illegible], the clips being enclosed in the fibrous tissue without signs of inflammation or intolerance. The fact must be added that the special characteristic of the method is the *extramucous closure*, that is to say, the clips do not cross the [illegible] wall but the small teeth cross the peribronchial tissue and [illegible] to the cartilage and/or "ligamentum" perhaps to the muscular [illegible] outside the mucosa.

It is possible to object to this method because the quantity of foreign [illegible] in the wound is greater than in other procedures described above. [illegible] happened on various dogs there is a danger that the clips [illegible]. However, when both edges of the stump were well coapted [illegible] the clips on the corners were placed in a perfect oblique [illegible] with the closure obtained the necropsy [illegible] of this method and confirmed the ideas maintained.

[illegible] experiment and the day after the oper[illegible]

[illegible] of the silver or the V2A steel ones [illegible] to [illegible] hardly [illegible] experience, although [illegible]

As the series presented is rather small we think it would be convenient to continue the experiments before deciding to use it on human beings

SUMMARY

An original method of extramucous closure with special silver and V2A steel clips is described by which a good bronchial stump closure is obtained

The teeth of the clips do not cross the whole bronchial wall, they respect the mucosa

The results of using the method in fifteen dogs are discussed, showing the advantages and disadvantages

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BRAIDED TANTALUM AS A BRONCHIAL SUTURE MATERIAL

EXPERIMENTAL AND CLINICAL OBSERVATIONS

THOMAS I. KEYES, M.D.
SALT LAKE CITY, UTAH

STAINLESS steel wire is now quite widely used by thoracic surgeons as a bronchial suture material. However, it possesses the disadvantages of being [illegible] difficult to handle and of kinking when the knot is being brought down.

An attempt was therefore made to find another equally suitable suture material not possessing these disadvantages to the same degree. Such a suture material was found in braided tantalum.

The latter possesses the tensile strength and inertness of stainless steel wire and less tendency to kink. It may be described as being "in between" silk and stainless steel in this regard.

TABLE I. RESULTS OBTAINED

[illegible]	[illegible]	[illegible]	[illegible] OPERATED	DATE [illegible]	OPERATIVE PROCEDURE	TYPE OF SUTURE	CONDITION OF BRONCHIAL STUMP
1	M	[illegible]	[illegible]	July 1[illegible]	Rt. upper lobectomy	CT	Primary healing, stump covered with epithelium
	"	[illegible]	[illegible]		Lt. lower lobectomy	IT	No fistula present
			[illegible]		Rt. upper and middle lobectomy	CT	Bronchus closed and appeared healing well
				April [illegible]	[illegible] wound [illegible] sacrificed		
	"		[illegible]	[illegible]	Rt. [illegible] lobectomy	CT	Stump healed and covered with epithelium
[illegible]	"	[illegible]	[illegible]	[illegible]	Lt. upper lobectomy	CT	Primary healing and covered with epithelium
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		This animal was used recently, sacrificed by another department
[illegible]	[illegible]		[illegible]	[illegible]	[illegible] middle lobectomy	IT	Primary healing covered with epithelium
[illegible]			[illegible]	[illegible]	[illegible] lobectomy	IT	[illegible]
			[illegible]	[illegible]	[illegible]	IT	[illegible]
[illegible]			[illegible]	[illegible]	[illegible]	IT	[illegible] covered with epithelium

[illegible]

tantalum was used either continuously or in an interrupted manner on the cut end of the bronchus All nine dogs (with the exception of one which was inadvertently destroyed) were sacrificed after varying periods of time In no case, at the time of operation, was *the bronchial stump covered or an antibiotic* used Table I demonstrates the results obtained

Examination of the specimens was done by a competent pathologist who found primary healing taking place in all cases There was no evidence that in these cases healing occurred by opening up of the bronchus and the formation of plug as found by Rienhoff

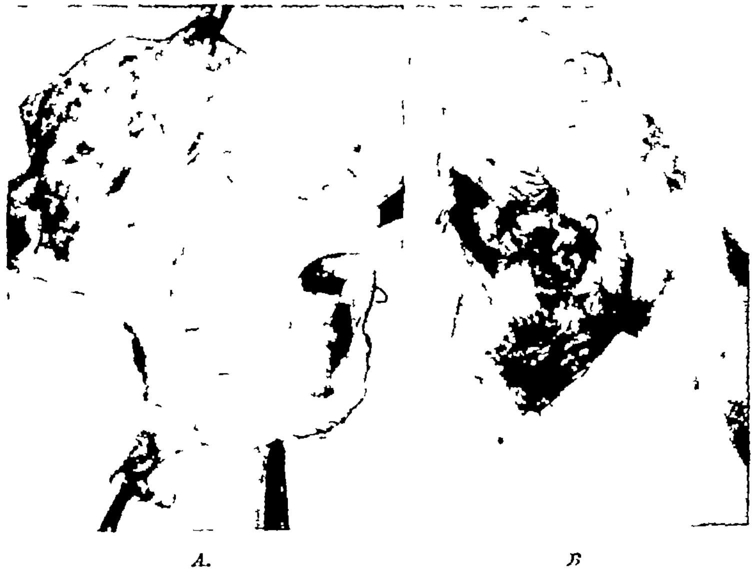

Fig 1 —A The trachea and bronchial stump inner aspect in Dog 8 fourteen days post operatively Note that healing is taking place and the stump has not opened up B External view of the stump Sutures are seen No epithelization is noted as yet at early date

This suture material was used on four human beings in three lobectomies and one segmental resection without untoward results

I believe that in human patients a heavier suture such as 000 tantalum would be better to use than 0000 because of the greater thickness and toughness of the human bronchus

SUMMARY

A new bronchial suture material is described which is equally as good as stainless steel wire but easier to handle First impressions from a small series of cases indicate that it can be used in tuberculous cases or in other cases where stainless steel wire is used

The suture material for the experiment was furnished by Johnson & Johnson Co (Ethicon Suture Laboratories, Incorporated), New Brunswick, N J

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PAPILLOMA OF THE BRONCHUS

CASE REPORT

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TORONTO, ONT.

PAPILLOMAS of the bronchus have been reported, but it is difficult to determine what percentage of benign endobronchial tumors are true papillomas. The literature is not of much help because the name ' papilloma ' has been somewhat loosely applied to a variety of lesions within the bronchus, some of which are inflammatory in origin and are not true neoplasms.[1] There is no doubt, however, that true papilloma is a rare tumor of the bronchus and an uncommon cause of bronchial obstruction.

A study of four cases filed as papilloma of bronchus in the Department of Surgical Pathology, Toronto General Hospital, revealed that three of them are probably of inflammatory origin. The fourth is probably an endobronchial [illegible]. A recent case which came to our attention following lobectomy by Dr. F. Kergin of the Department of Surgery, Toronto General Hospital, more [illegible] fulfills the requirements of a true papilloma.

CASE REPORT

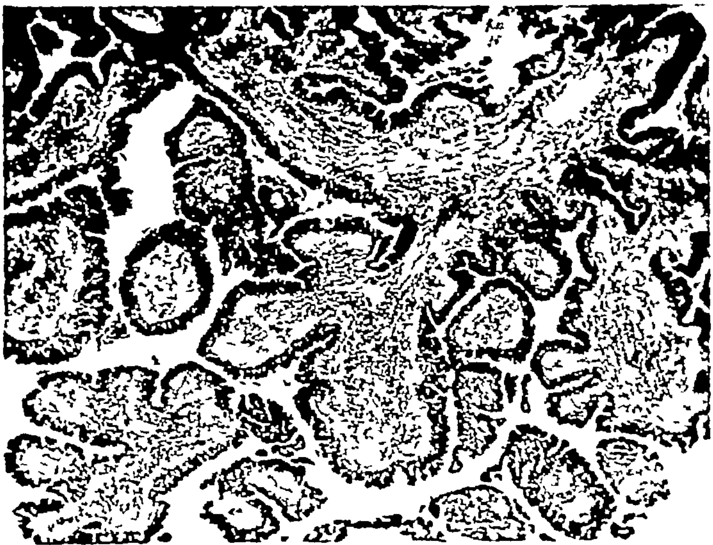
[illegible] married white woman. She had been in good health [illegible] respiratory system until three years before admission [illegible] of hemoptysis [illegible] for one day, [illegible] cupful of bright blood. Following this she was [illegible] when she had a very similar episode. On [illegible] and she was told that she had pneumonia. [illegible] lipiodol bronchogram were made without [illegible] she was again well with no symptoms [illegible]

[illegible] lasting two to three [illegible] persistent cough, productive of [illegible] symptomatology [illegible] postero-laterally [illegible] bron[illegible] [illegible] normal

[illegible]

appearance explained the diagnosis of normal bronchial mucosa reported on the biopsy specimen. The remainder of the lobe showed a chronic interstitial pneumonitis It was considered unlikely that the tumor was of inflammatory origin, and its histology conformed with the accepted definition of papilloma

Fig 1



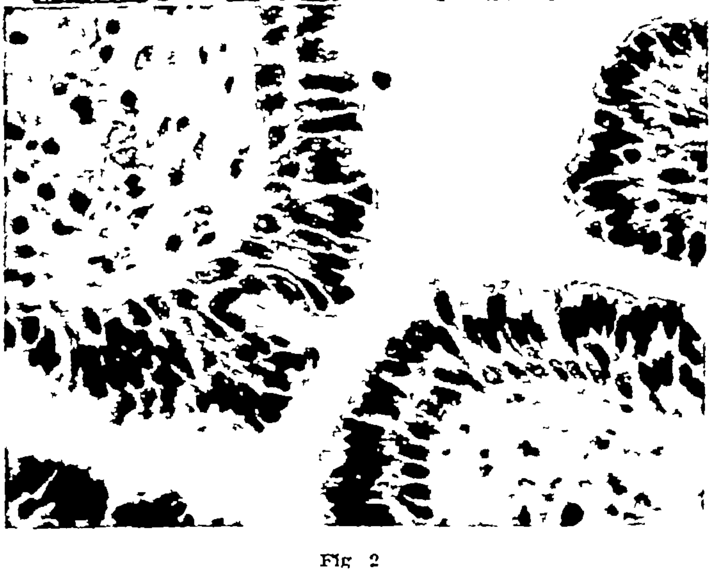


Fig 2

Figs. 1 and 2 —Papilloma of bronchus high and low-power magnification

The patient made an excellent recovery, and was discharged from the hospital free of symptoms

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BRONCHIAL ADENOMA IN CHILDREN

A CASE REPORT OF A 7-YEAR OLD BOY

D. E. WARD, JR., M.D.,* H. H. BRADSHAW, M.D., AND THOMAS C. PRINCE, JR., M.D.

WINSTON-SALEM, N. C.

ADENOMA of the bronchus is a rare tumor in the pediatric age group. Bronchial adenoma was first recognized seventy one years ago, and yet it [illegible] little attention until relatively recently. Only eight cases of adenoma [illegible] could be found reported in the available literature in children under [illegible] years of age. These eight cases have been reviewed, and a case of [illegible] bronchus in a 7 year old boy treated by pneumonectomy is re[illegible]. [illegible] in thoracic surgery and anesthesia have broadened [illegible] approach to these tumors in children.

Mueller in 1882 was the first to report a case of bronchial adenoma. He [illegible] at the autopsy of a woman who had died from suppurative [illegible] which had persisted for eight years. Patterson[2] in 1930 found [illegible] recorded in the literature, ten of which were diagnosed at post- [illegible] remaining sixteen were diagnosed during life. Kramer and [illegible] recommended bronchoscopic treatment with the use of radon seeds [illegible] brought attention to the tumor and encouraged endoscopic [illegible]

The [illegible] bronchial adenoma has been stated to be 6 per cent of all [illegible] tumors. Kramer and Som found 23 adenomas among 353 [illegible] tumors. Of 217 histologically proved primary lung tumors [illegible] 15 were bronchial adenomas, an instance [illegible] 12 per cent of 278 neoplasms diagnosed bron[illegible] is that the tumor is being recognized [illegible]

[illegible] eight cases of bronchial adenoma found [illegible] the available literature. The patient [illegible] youngest in my [illegible] from 9 to [illegible] and four were treated [illegible] reported by [illegible] 7 year old child

TABLE I BRONCHIAL ADENOMAS REPORTED IN CHILDREN UNDER 14 YEARS OF AGE

AUTHOR		AGE	SEX	LOCATION OF TUMOR	TREATMENT	RESULT
Kramer and Som[3]	1935	13	?	Not reported	Bronchoscopic removal locally followed by radiotherapy	Unknown
Rosenblum and Klein[13]	1935	11	M	Right main bronchus	Bronchoscopic removal locally	Clearing of atelectasis 2 mo later by x ray
Peterson[18]	1936	11	?	Unknown	Unknown	Unknown
Jones, MacKenzie, and Biddle[14]	1943	10	M	*Right main* bronchus	—	Died during bronchoscopy
Jackson, Konzelmann, and Norris[4]	1945	13	M	Right main bronchus	Bronchoscopic removal by forceps and *electrocoagulation*	Symptomatic cure 3½ yr
Souders and Kingsley[15]	1948	13	M	Left main bronchus	Partial bronchoscopic removal Left pneumonectomy elsewhere	No follow up
Som[16]	1949	13	?	Unknown	Bronchoscopic removal	Unknown
Smoller and Maynard[17]	1951	9	F	Right middle lobe bronchus	Pneumonectomy with thoracoplasty	Excellent—10 mo P O

Present Illness—The child had been in apparent good health until June, 1952, at which time he developed "pneumonia" of the left lung, which was treated with penicillin Subsequently, he developed a cough which persisted for several weeks and he complained of a pain in the left thorax Although he improved, he was never well according to his parents

In October, 1952, he again developed fever, and the condition was diagnosed as "pneumonia" of the left lung He was treated with penicillin with improvement On Nov 1, 1952, a chest x ray picture revealed a density suggesting an atelectasis of the left lower lobe The patient was treated with Chloromycetin and sulfa drugs Improvement was again noted, but on Nov 28 1952 the patient had a high fever and was returned to the hospital A chest x ray film showed atelectasis of the left lower lobe, and the patient's temperature was 103° F The child was treated with penicillin and Terramycin, but failed to improve A diagnosis of bronchial obstruction was made and the child was transferred to the North Carolina Baptist Hospital, Winston Salem, N C, for further treatment

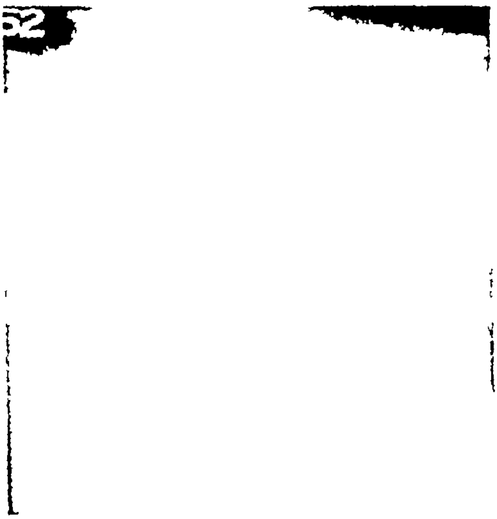
Physical Examination—On admission the temperature was 104° F pulse 120 per minute, respiration 28 per minute, and blood pressure 96 systolic over 60 diastolic He was a thin, pale looking boy, who appeared chronically ill and weighed 41 pounds

The trachea and heart were found deviated to the left side The chest was asymmetrical with increased expansion over the right side Tactile fremitus was absent over the left side except over the upper lobe Dullness to percussion was present over the left lower chest, and breath sounds were absent over the left lower lobe No rales were heard No murmurs were heard in the heart, and no organs or masses were palpable in the abdomen No lymph nodes were enlarged or tender

Laboratory Data—Hemoglobin was 14 Gm, red blood cell count 4,600,000, corrected sedimentation rate 48 mm per hour, white blood count was 26,750, with 80 per cent polymorphonuclearphils and 20 per cent lymphocytes Urinalysis was negative Wassermann and Kahn tests were negative Alpha streptococcus and nonhemolytic staphylococcus were cultured from the throat Three blood cultures produced no growth Tuberculin skin test was negative Chest x ray film (Fig 1) showed evidence of atelectasis of the left lower and left upper lobes with marked shift of the mediastinal structures toward the left side No foreign body was visualized

Course in the Hospital—On Dec 11, 1952, at bronchoscopy a tumor in the left main bronchus (Fig 2) was visualized A biopsy was taken which the pathologist thought represented a bronchial adenoma On Dec 15, 1952 a left pneumonectomy was done under endo [illegible] The left lower lobe was found to be [illegible] The left upper lobe was emphysematous and would not deflate.

[illegible] was done by individually ligating the arteries and veins. The [illegible] made from [illegible] lesion attached to the superior wall of [illegible] 0.7 by 1.0 by 0.5 cm. in size. The left main bronchus



[illegible] of the left lung

was severed proximal to the tumor and was closed with interrupted sutures. A frozen section obtained on a hilar lymph node during the operation was reported negative for tumor. A partial thoracoplasty was done with resection of the fifth, sixth, and seventh ribs on the left side.

Postoperative Course.—The patient was given daily penicillin and dihydrostreptomycin and had an uneventful postoperative course. Fig. 3 shows the postoperative x-ray picture. The child was discharged on the ninth postoperative day in good condition. Three months later the child was examined and had no cough, chest pain, or other respiratory symptoms.

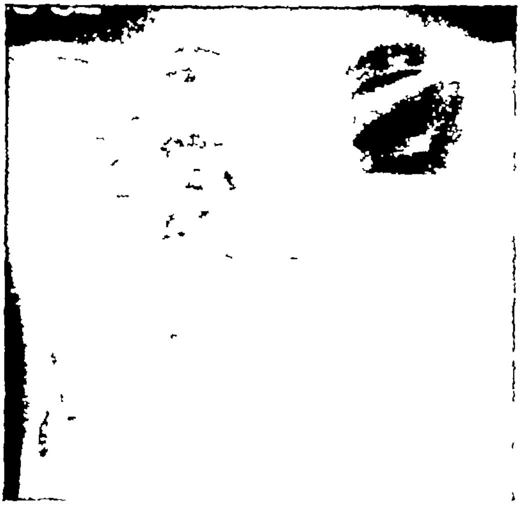


Fig. 3.—Postoperative chest x-ray film taken after left pneumonectomy.

DISCUSSION

Bronchial adenoma is an uncommon tumor below the age of 14 years. A review of the literature shows that the lesion does occur in children and should be thought of when bronchial obstruction is found. The symptomatology of bronchial adenoma is that of any other type of bronchial obstruction. An important symptom of bronchial adenoma is hemoptysis, which is attributable to the marked vascularity of the tumor. A definite diagnosis can be established by bronchoscopy and biopsy of the lesion.

Bronchial adenoma may be locally invasive or may metastasize by way of the lymphatics or blood stream.[7, 8] Metastases to the liver, vertebral bodies, opposite lung, and kidney have been reported.[9, 10] Goldman[11] presented a report on five patients showing malignant qualities in bronchial adenomas. Clerf and Bucher[7] reported a case of bronchial adenoma in which biopsy from the bronchus was examined histologically at intervals over a five-year period, at the end of which time carcinomatous change was detected in the tumor. That finding was confirmed at autopsy. Umiker and Storey[12] reported a case of peripherally located bronchial adenoma with a histologic evidence of transformation into adenocarcinoma six years following detection. A right upper lobectomy was done and the tumor was reported as "well differentiated adenocarcinoma."

[illegible] much discussion in the past concerning the treatment of [illegible] bronchus. It is never possible to tell from bronchoscopic examination [illegible] tumor extends through the bronchial wall as a "dumbbell [illegible] into the surrounding lymph nodes. It has been proved that [illegible] grow and metastasize as a tumor of low grade malignancy. [illegible] clear now that excision of the entire tumor and surrounding [illegible] adequate treatment. This can best be done by a lobectomy or [illegible]

SUMMARY

[illegible] bronchial adenoma in a 7 year old boy treated by pneumonectomy [illegible]. A review of the literature of eight cases of bronchial adenoma [illegible] years of age is included. A plea is made to treat [illegible] malignant lesion with pneumonectomy or lobectomy as [illegible] present to cure the tumor.

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[illegible]

[illegible] Med. [illegible]

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[illegible]

[illegible]

ENDOBRONCHIAL HAMARTOMA

REPORT OF TWO CASES

J M YOUNG, M D, ELISE JONES, M D, FELIX A HUGHES, M D,
FRANCIS E FOLEY, M D, AND JOHN R FOX, JR, M D
MEMPHIS, TENN

THE TERM hamartoma was first introduced in 1904 by Albrecht,[1] who used it in reference to benign mixed tumors occurring in various organs He described them as tumor-like malformations due to abnormal mixing or abnormal development of the normal tissue components of the organ in which they occur This abnormality may be the result of variations in the quality, arrangement, or degree of differentiation of the tissues Many lung hamartomas have been reported as chondromas, lipomas, osteochondromas, etc, but are hamartomas according to Albrecht's criteria Yet, pure lipomas[2] and fibromas[3] have been reported Hamartomas are generally described as circumscribed or diffuse, the former being more common Most often they occur in the periphery of the lung and produce few, if any, symptoms They are said to occur about once in each 400 individuals[4] and are more common in male patients

This article, however, deals only with the endobronchial hamartomas which are much less common and which frequently produce symptoms because of obstruction of the bronchi The usual symptoms are cough, hemoptysis, purulent sputum, wheezing, pain, fever, and dyspnea, in that order of frequency[5] Recently we have observed two of these unusual endobronchial tumors

CASE REPORTS

CASE 1—J N, a 59 year old white man, was hospitalized Jan 12, 1953, with a three months' history of a cough productive of whitish, mucoid sputum, occasionally streaked with blood He denied dyspnea, chills, fever, and weight loss His physician told him that chest x ray examination disclosed an "opacity of the lung" He was transferred to this hospital Feb 11, 1953, for definitive diagnosis and treatment

The physical examination was essentially negative, and the routine laboratory examinations were not remarkable The chest x ray examination, however, disclosed a *mottled* infiltration in the lower right lung field, felt to be pneumonitis

Bronchoscopy showed a bluish red knobby tumor at a division of the right middle lobe bronchus A previous bronchoscopy at another Veterans Administration hospital had also disclosed this polypoid tumor, but the biopsy was not diagnostic The biopsy taken here showed *fragments of respiratory epithelium, fat, hyaline cartilage, and bone, hamartoma* was considered the likely diagnosis

On Feb 17, 1953, a right middle lobectomy was performed, and the patient had an uneventful postoperative course

Pathology—The gross specimen (Fig 1) was a *firm*, atelectatic right middle lobe At the bifurcation of the middle lobe bronchus was a *firm, pink*, bosselated tumor mass measuring approximately 2 0 cm in length and 1 0 cm in diameter This arose from the wall of a tertiary bronchus near its origin

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From the Laboratory Service and Thoracic Surgery Section of the Surgical Service Veterans Administration Medical Teaching Group Hospital

Received for publication July 7 1953

Fig 1

Fig 2

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[illegible] A Case Report [illegible]
[illegible]
[illegible] Cases [illegible]
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ENDOBRONCHIAL HAMARTOMA

REPORT OF TWO CASES

J. M. YOUNG, M.D., ELISE JONES, M.D., FELIX A. HUGHES, M.D.,
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On Feb. 17, 1953, a right middle lobectomy was performed, and the patient had an uneventful postoperative course.

Pathology.—The gross specimen (Fig. 1) was a firm, atelectatic right middle lobe. At the bifurcation of the middle lobe bronchus was a firm, pink, bosselated tumor mass measuring approximately 3.0 cm. in length and 1.0 cm. in diameter. This arose from the wall of a tertiary bronchus near its origin.

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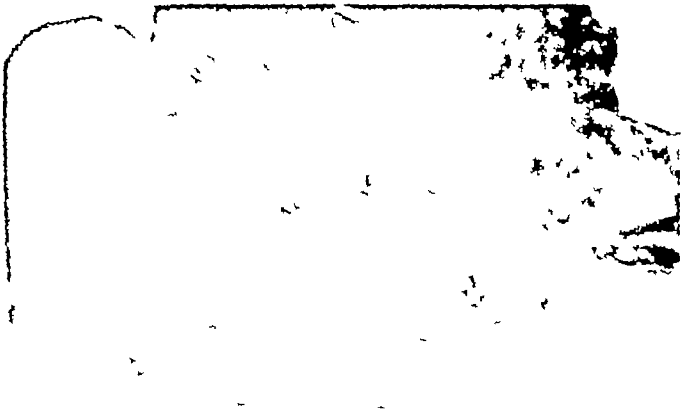

Fig. 1

Fig. [illegible]

Microscopically, the tumor consisted of cartilage masses in disorganized arrangement with fat and myxoid connective tissue between. Many of the pieces of cartilage were undergoing ossification with formation of thin trabeculae of bone and fat-filled marrow spaces, and a few of the marrow spaces contained marrow elements (Fig. 3). The largest mass of cartilage and bone had its origin from cartilage in the deeper part of the bronchial wall (Fig. 2). The tumor surface was covered by respiratory epithelium, which in a few areas showed squamous metaplasia.

Sections from the lung parenchyma disclosed a cellular fibrous pleura infiltrated with chronic inflammatory cells. The alveolar walls were thickened and fibrous, the bronchi were moderately dilated, and a few contained purulent exudate. The alveolar spaces showed hemosiderin-laden macrophages in moderate numbers.

CASE 2.—R. W., a 62-year-old white man, was admitted to a distant hospital on Jan. 30, 1953, following an episode of coughing and hemoptysis. There were no such previous episodes, and the past history was noncontributory. There had been no fever, pain, or chills. On Feb. 18, 1953, he was transferred to this hospital for further study and treatment.

Physical examination was essentially negative. Sputum was smeared and cultured for acid-fast bacilli and fungi and reported negative. Serial x-ray films disclosed emphysema of the right lower lobe with a suggestion of a right hilar density which possibly represented a tumor in that area obstructing the right lower lobe bronchus.

On Feb. 25, 1953, a bronchoscopy disclosed a pink, globular tumor arising from the posterolateral wall of the right intermediate bronchus. This was biopsied, but only respiratory epithelium showing some squamous metaplasia was obtained. A previous bronchoscopy at another Veterans Administration hospital had also shown this tumor.

On March 9, 1953, a right middle and lower lobectomy was performed. The postoperative course was uneventful.

Pathology.—The gross specimen showed near the line of resection of the bronchus, a polypoid, fusiform mass measuring 3.0 cm. in length and 1.2 cm. in diameter (Fig. 4). It was smooth and pink, soft in some areas, and firm in others. On section it contained calcified cartilage (Fig. 5) and arose from the wall of one of the branches of the middle lobe bronchus. The bronchi were reddened and contained much mucoid material. The middle lobe was completely atelectatic, the lower lobe was crepitant.

Microscopically, the tumor was covered with respiratory epithelium showing areas of squamous metaplasia. The stroma was composed of a well-vascularized myxoid fibroreticular tissue. There were fat cells, mucus glands, and masses of cartilage present. Numerous bundles of smooth muscle were found beneath the epithelium but not within the cartilage. There were small inclusions of fat cells within the cartilage. Most of the tumor was composed of an irregular lobulated mass of cartilage, but multiple sections disclosed other smaller separate collections of cartilage cells in the base of the tumor. In many areas the cartilage showed degenerative changes, but no osseous metaplasia was present. The lung parenchyma showed areas of emphysema, foci of round cells, and some diffuse scarring of the alveolar walls. There was atelectasis and fibrosis present in the middle lobe.

DISCUSSION

A review of the literature discloses twenty-four cases of endobronchial hamartoma reported. Postlethwait, Hagerty, and Trent[6] in 1948 reviewed twelve cases and reported one of their own. In 1951 Effler and Scheid[7] added another case. Sherrick[8] in 1952 collected nineteen cases and added still another. Rubin and Berkman[5] reported twenty-eight cases where hamartomas were found at autopsy, and one of these arose from the right middle lobe bronchus. They also included three other cases where pulmonary resections had disclosed [illegible] but none of these were endobronchial. Recently, Nissen and his [illegible] reported a case of osteochondroma of the bronchus making a total of [illegible] four including our own cases.

Of the twenty four cases now reported thirteen arose in the right lung and [illegible] in the left lung. Seven were incidental findings at autopsy and the [illegible] produced symptoms.

Womack[1] and Graham[4] felt that these tumors represent failures of embryonic bronchial buds to develop normally. Other etiological possibilities

FIG. 4

mentioned are that these growths represent hyperplasia of normal structures reactions to inflammation, and true neoplasms The most generally accepted belief, however, is that they are congenital in origin

Most hamartomas show a preponderance of hyaline cartilage, but a careful search of sections from the tumors often discloses, in addition, fat, bone, and epithelial derivatives The cartilage often undergoes calcification and sometimes even ossification as in our Case 1, where fat-filled marrow spaces were present Marrow elements may be present as was noted by Nissen and his co-workers[9] and in our Case 1 Marrow elements are occasionally found in ectopic bone formation so probably do not constitute a true part of the tumor Fat in most of these tumors is probably only a filler material representing metaplastic change in connective tissue Fat has been noted to occur normally in the bronchial wall[2] The muscle likewise probably represents only a normal component of bronchial wall, and the epithelium merely covers the tumorous projection or lines passages through the growth

The presence of bone with the cartilage suggests the diagnosis of osteochondroma, but we feel that the bone merely represents a metaplastic change with aging of the hyaline cartilage Ossification of bronchial cartilage rings has been noted in adults[2] Thus the principal component of these tumors is cartilage In most cases where the type of cartilage has been identified, it has been of the hyaline type, as was true in our two cases Moore,[11] however, found elastic cartilage in his case and postulated that the cartilage was ectopically placed

Liebow[4] has separated the chondromas and osteochondromas from the hamartomas, but a review of the microscopic features of the reported endobronchial hamartomas shows no clear cut features for differentiation of these groups For the purposes of simplification it seems desirable to include these tumors all in one group, the hamartomas, since this term is inclusive and deeply entrenched in medical literature

These tumors particularly those situated in the lung periphery, are now diagnosed more frequently with the increase in pulmonary resections for silent lung lesions Though these are almost always benign, the true nature of the tumor is disclosed only by operation and microscopic study of the tumor

Endobronchial hamartomas have occasionally been removed through the bronchoscope, and none have been reported to recur In other instances, as in our own cases, the tumors are not favorably situated for this type of procedure Often they produce recurrent bouts of pneumonitis and atelectasis and make it desirable to remove the involved segment The most frequent symptoms noted have been cough and hemoptysis The roentgenograms in our cases were not diagnostic of bronchial tumor

SUMMARY

Two cases of endobronchial hamartoma are reported and discussed Both were treated by lobectomy

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A PRACTICAL PHYSICAL METHOD FOR THE DETECTION OF EARLY RESPIRATORY ACIDOSIS DURING THORACIC SURGERY

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Minneapolis, Minn

PREVIOUS work from this and other laboratories has adequately demonstrated the common occurrence of acidosis during thoracic surgery[1] We have presented evidence that such acidosis stems from inadequate alveolar ventilation during the period of anesthesia[1] Similar conclusions were reached by Taylor and Roos[3] in 1950 and by von Buhlmann and Hotz[7] in 1951 The previous studies from this laboratory were performed during open chest procedures while the patient was anesthetized with intravenous Pentothal Sodium curare Ventilation was accomplished by intermittent positive pressure (manual) through an endotracheal tube

This article is a description of a simple method for the detection of an early and slight rise in alveolar PCO_2

METHODS

Many of the methods used in this work were the same as those used in the determination of alveolar ventilation during thoracic surgery[1] In addition, pressure tracings were recorded by means of a strain gauge from one of two points (1) the trachea by means of a polyethylene tube (polyethylene, size 240) inserted through the endotracheal tube, and (2) at the anesthesia bag (Fig 1) In several instances recordings were taken from both points simultaneously and recorded on a single tracing by means of a two channel Sanborn recorder The PCO_2 threshold of the respiratory center was checked by frequent determinations of the arterial blood PCO_2 in the manner previously described An indwelling polyethylene tube (polyethylene, size 90) in the brachial artery gave ready access to arterial blood samples

Such pressure recordings were made in fourteen patients who were undergoing thoracic surgery for tuberculosis and who were under Pentothal curare anesthesia with intermittent manual positive pressure ventilation (controlled ventilation) Eighty four determinations were made of arterial blood PCO_2 in order to establish the respiratory threshold for PCO_2 under the conditions of an open chest and Pentothal curare anesthesia

The pressure tracings taken from the trachea and the anesthesia bag varied both quantitatively and qualitatively (Fig 2A) The differences were accounted for primarily by the lag in the system created by the resistance in the tubing from the anesthesia bag to the end of the endotracheal tube The patient's spontaneous respiratory efforts created greater negative pressure in the trachea than in the anesthesia bag (Fig 2B) Since it was the detection of the patient's own respiratory effort that concerned us, the endotracheal tracing proved to be the more sensitive for this study

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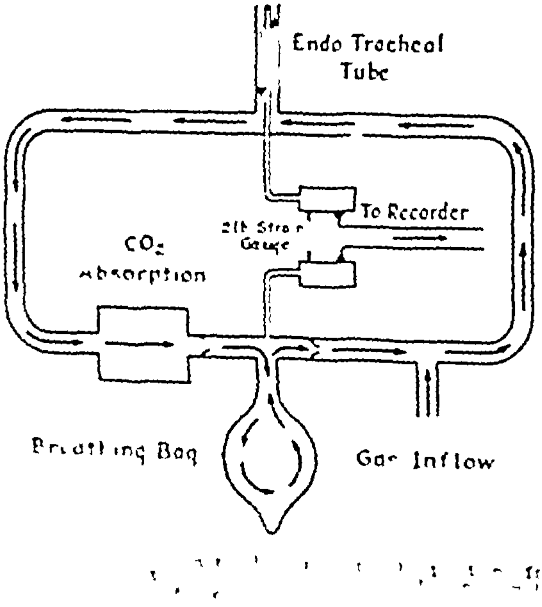
RESULTS

[illegible] correlation was found between the level of the arterial [illegible] PCO_2 and the presence or absence of spontaneous respiratory efforts by [illegible] patient (Pentothal curare) with an open thorax. In the pres [illegible] ted PCO_2 the patient made spontaneous respiratory efforts whenever [illegible] pause in the intermittent positive pressure administered by [illegible] dogs. In the presence of a normal or low PCO_2 in the arterial blood there were no such spontaneous respiratory efforts on the part of the [illegible]. The pressure tracing was flat during pauses of 5 to 10 seconds in the [illegible] pressure when the PCO_2 was normal or low. This indicated [illegible] at these times. Such pauses were marked by rhythmic [illegible] fluctuations [illegible] the PCO_2 was elevated (Figs. 2 through 6). [illegible] intermittent positive pressure administration are denoted by the word [illegible] in Figs. 2 through 6.



[illegible]

[illegible] made [illegible] In the [illegible] mittent positive pressure were then determined. This patient had shown a good correlation previously with a threshold of PCO_2 at about 45 to 47 mm Hg during the first ninety minutes of the intrathoracic procedure. When he was quite deeply anesthetized by a booster injection of Pentothal curare intravenously, a PCO_2 of 80 mm Hg in the arterial blood elicited no spontaneous efforts. Whether this lack of spontaneous effort was due to paralysis by curare or to dulling of the respiratory center by Pentothal could not be determined.

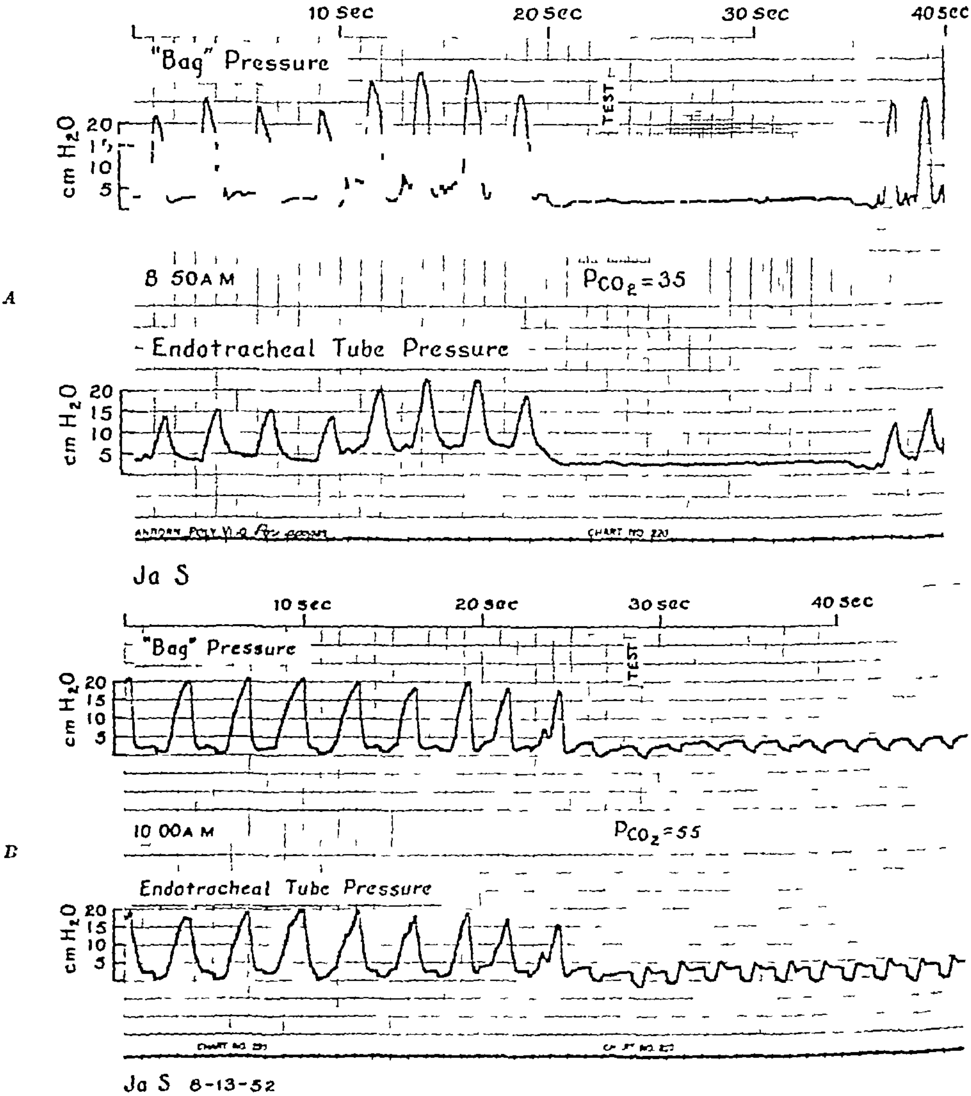
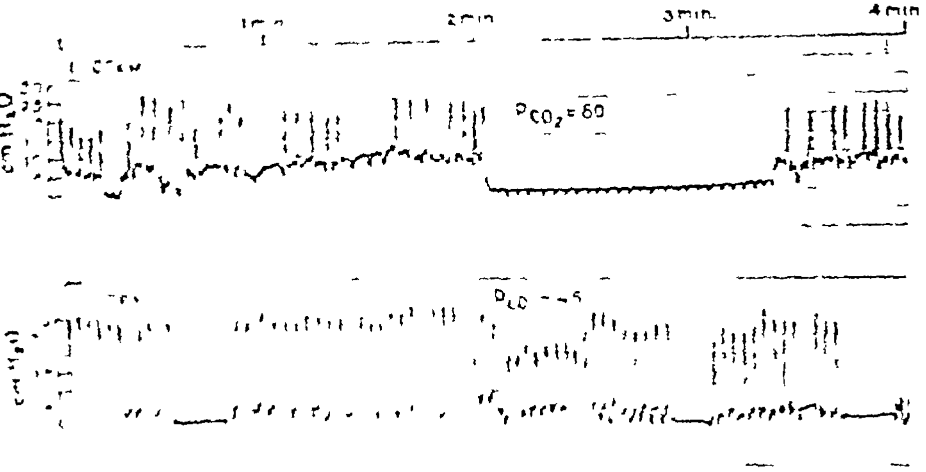
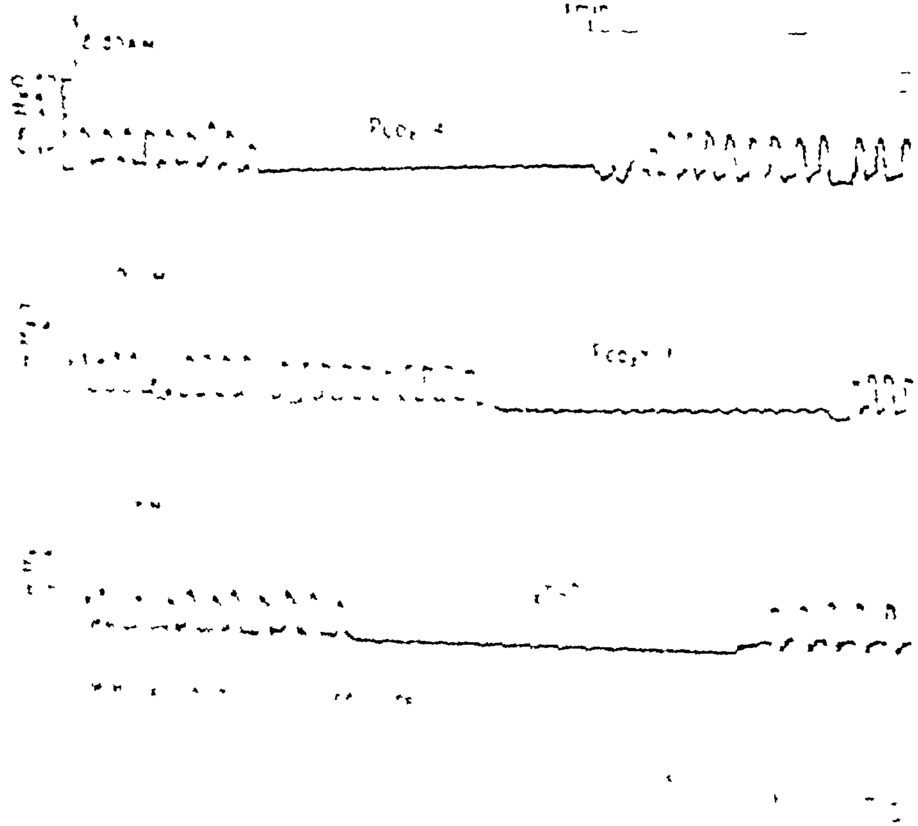


Fig. 2.—A. Simultaneous tracings from the endotracheal tube (below) and from the anesthesia bag (above). The area marked "test" represents a twenty second lapse in the intermittent positive pressure and the absence of spontaneous respiratory efforts indicate true apnea at a time when the PCO_2 was below the threshold. B. The same patient at a later time when the PCO_2 exceeded the threshold of the respiratory center. During the "test" period spontaneous respiratory efforts are clearly seen. The negative pressures are more clearly shown in the tracing from the catheter in the endotracheal tube.



[illegible] P_{CO_2} of 5 mm. Hg and [illegible] mm. Hg more [illegible]



DISCUSSION

Some comment is in order concerning the value of maintaining a near normal physiologic state during major surgery. The patients whose PCO_2 was maintained near normal showed a more rapid recovery from the anesthesia than did those whose PCO_2 was elevated significantly. It is common for a patient anesthetized with Pentothal-curare not to require much drug during the last hour of a major procedure. It seems likely that in such instances rather severe degrees of CO_2 accumulation may play a definite role in maintaining anesthesia and in slowing recovery.

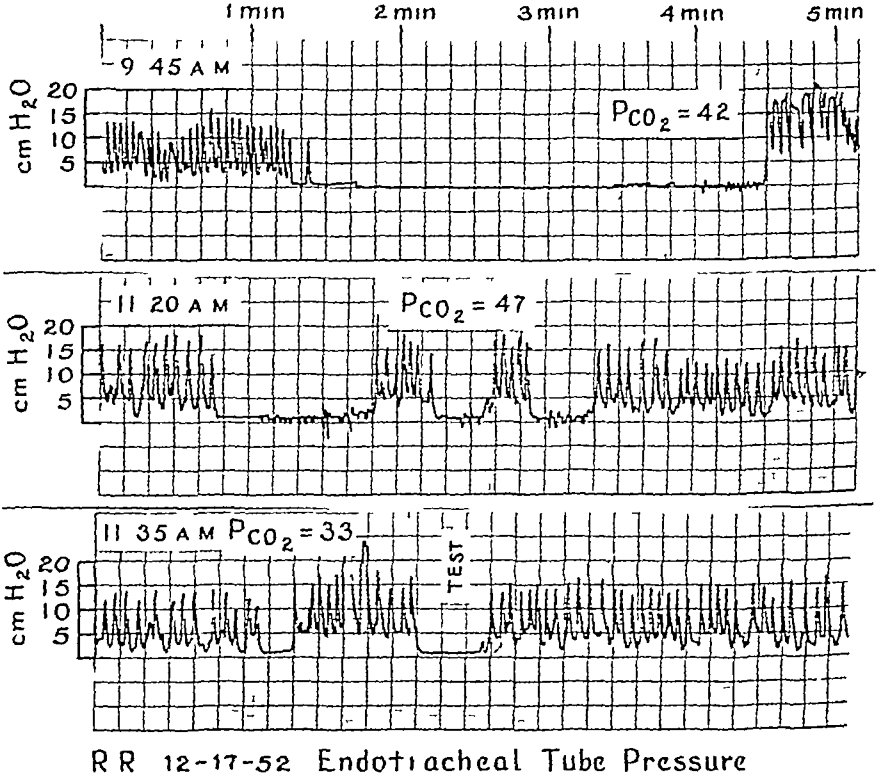
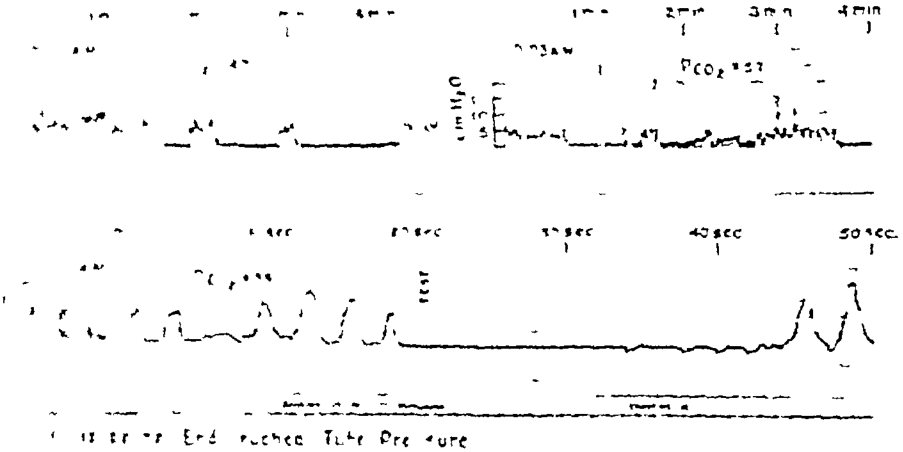


Fig. 5.—Endotracheal tube pressure recording shows the early development of spontaneous respiratory efforts at a PCO_2 of 42 mm Hg. Later at a PCO_2 of 47 mm the magnitude of these efforts was better developed. At a PCO_2 of 33 true apnea existed during pauses in artificial ventilation.

Tachycardia is not uncommon during major thoracic surgery. In this series of patients acidosis was frequently accompanied by tachycardia. This would suggest a toxic effect of acidosis upon the myocardium and might explain some cases of cardiac arrest or ventricular fibrillation during anesthesia. Acidosis is particularly dangerous in the presence of anoxia because the two abnormalities are probably additive in their detrimental effect upon the body. We have observed such a combination in one patient who suffered an irreversible cardiac arrest. This event had been preceded by a two hour period of tachycardia.

T[illegible] exerted upon the bag varied greatly from one anesthesiologist [illegible] even during a given procedure under one anesthesiologist. The [illegible] 15 to 25 cm. water positive pressure. In general after [illegible] as for the starting of a transfusion) there was a tendency [illegible] respirations of high pressure (25 to 35 cm. water) and to hold [illegible] pressions so that there was an expiratory resistance of 6 [illegible]. Such respiratory assistance is obviously not as efficient as a [illegible] complete emptying of the lung between respirations.



[illegible] at PCO₂ [illegible] min [illegible] The [illegible] PCO₂

[illegible] maintain an adequate ventilation by deliber[illegible] 15 to 20 cm. [illegible] at a rate of 12 to 14 [illegible] pressure by [illegible] bag compressions. The [illegible] complete expiration [illegible] and thus makes [illegible] The [illegible] phase should be at least twice [illegible] in order to allow for [illegible] on one lung some [illegible] collapse of [illegible] may fail, but this is probably uncommon in usual practice Whether such negative pressures will be adequate to activate the Emerson assistor remains to be seen

Maloney, Derrick and Whittenberger[8] have pointed out that good relaxation is easier to obtain in the presence of good ventilation than when the patient is restless due to acidosis Actual struggling was noted in some of our patients when the PCO_2 was moderately elevated (PCO_2 of 55 to 70 mm Hg) in spite of the actions of the Pentothal and curare Probably in some instances more anesthetic agent is given in order to abolish the restlessness which is due to acidosis More adequate ventilation might control the restlessness without the use of more anesthetic agent Certainly the respiratory center was active in the patients whose ventilation was controlled in accordance with the presence or absence of apnea during pauses in the intermittent positive pressure Anesthesia was quite adequate in these subjects without the necessity of deepening the level of anesthesia beyond the usual range

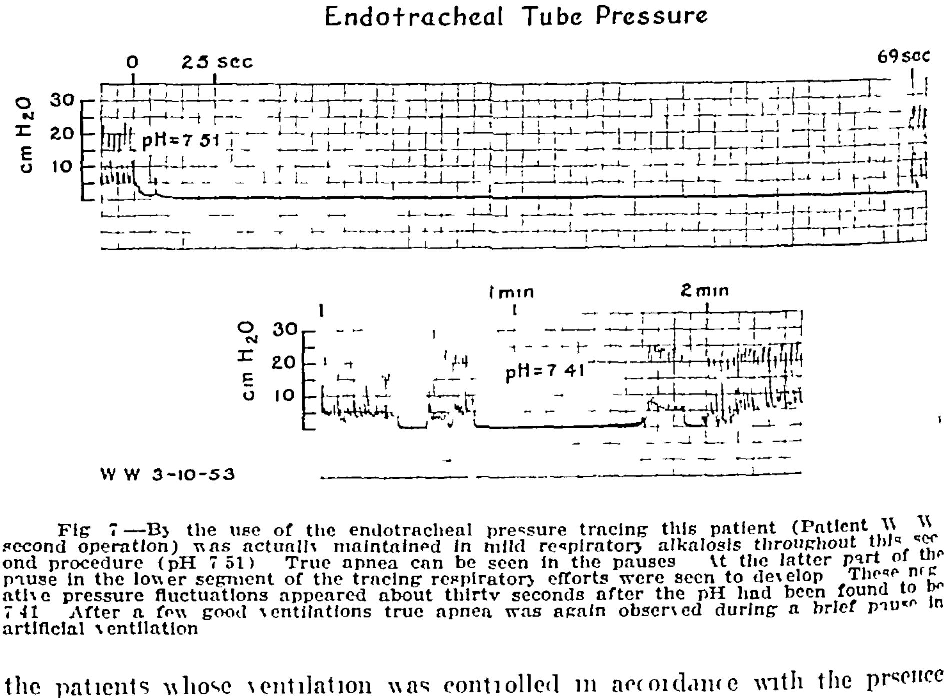


Fig 7 —By the use of the endotracheal pressure tracing this patient (Patient W W second operation) was actually maintained in mild respiratory alkalosis throughout this second procedure (pH 7 51) True apnea can be seen in the pauses At the latter part of the pause in the lower segment of the tracing respiratory efforts were seen to develop These negative pressure fluctuations appeared about thirty seconds after the pH had been found to be 7 41 After a few good ventilations true apnea was again observed during a brief pause in artificial ventilation

The practical application of such a method of detection of early respiratory acidosis is obvious It enables the anesthesiologist to observe the pressure pattern throughout the surgical period and to maintain a more nearly physiologic PCO This was actually done in the last nine patients in this study by means of the direct writing recorder Fig 7 shows the tracing of a second thoracotomy in patient W W whose first operation is represented in Fig 4 By observing the recording of the endotracheal pressure the anesthesiologist was able to maintain a mild respiratory alkalosis during the second operation [illegible] during endotracheal intermittent positive pressure respiration [illegible] tracheal pressure tracing is of great value. It would con- [illegible] in teaching proper technique of intermittent positive pres- [illegible]. The form of pressure curve clearly shows the manner in [illegible] is applied, the magnitude of the pressure reaching the [illegible] of inspiration and of expiration, the resistance to expiration [illegible] respiration.

[illegible] that the more experienced anesthesiologist actually feels [illegible] the same pressure fluctuations which we have recorded [illegible] to increase his efforts. Nevertheless, reports from various [illegible] that acidosis during intrathoracic surgery is the [illegible]. For this reason it is felt that any aid in detect- [illegible] acidosis should be useful. As yet there are no satisfac- [illegible] for the continuous recording of the pH, PCO_2 or CO [illegible]. The method described in this paper gives a simple indirect [illegible] PCO_2 during thoracic surgery under ordinary anesthetic [illegible] to substitute an ordinary sensitive aneroid manometer [illegible] order for the detection of spontaneous respiratory [illegible] simplification of the present method will be made sub- [illegible] that some such simple means should be practical. [illegible] no method for the detection of acidosis [illegible] judgment and experience in anesthesiology. The [illegible] paper is offered only as an aid to the anesthesiologist [illegible].

SUMMARY

1. A [illegible] of endotracheal pressure during positive [illegible]

2. [illegible] or PCO_2 is only slightly elevated and muscu- [illegible] Pentothal [illegible] anesthesia [illegible] dur- [illegible] permit the creation of detectable [illegible]

[illegible]

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PREGNANCY AND TUBERCULOSIS

A Report of Ten Cases Treated by Major Thoracic Surgery

H. M. HOLDEN, M.D., J. J. QUINLAN, M.D., V. D. SCHAFFNER, M.D., AND
J. E. HILTZ, M.D.
KENTVILLE, N. S.

AT THE Nova Scotia Sanatorium during the past fifteen years major thoracic surgery has been performed to control tuberculosis in ten pregnant patients. In five of them thoracoplasty operations were done, the other five underwent pulmonary resections.

[illegible] thoracoplasty during pregnancy has been referred to quite frequently in the medical literature, in only two cases has pulmonary resection [illegible] [illegible] as we could determine.

[illegible] discussed a case of pneumonectomy which was [illegible] for extensive caseous pneumonic disease in a 29 year old [illegible] who was pregnant. Convalescence was relatively uneventful [illegible] but the premature delivery of a 5 pound [illegible] infant occurred one month prior to term. Fourteen [illegible] after surgery both mother and child were in good condition. The [illegible] were negative. Streptomycin had not been administered [illegible]

[illegible] 25 year old patient with far advanced disease on [illegible] pneumonectomy was performed during the second month of [illegible] received streptomycin during the entire course of her pregnancy. [illegible] with the aid of low forceps.

[illegible] of the ten patients undergoing major thoracic surgery [illegible] Sanatorium during pregnancy are given in this article. [illegible] are presented first followed by the five cases of pul-

CASE HISTORY

[illegible] April 7, 19[illegible] April [illegible] on April 29, 1938 She was a primipara, 33 years of age, and was five months pregnant at the time Postoperative convalescence was uneventful Cesarean section was done on Sept 11, 1938, under spinal anesthesia A living child was delivered and there were no complications A chest film taken on Nov 23, 1950, was satisfactory, and twelve years following thoracoplasty this patient was leading a normal life

CASE 2—C D, aged 26 years, was admitted Feb 10, 1941, and discharged Dec 6, 1941 The history dated back to 1935 when this patient *failed to heed medical advice on the discovery of a parenchymal lesion and continued to lead a normal life* Four years later she complained of weakness and loss of energy A chest x ray film then revealed marked extension of disease and she was admitted to a tuberculosis unit in Cape Breton Cesarean section was carried out there on Jan 15, 1940, the patient was treated with bilateral pneumothorax She was discharged to her home in May, 1940, but further extension of disease was revealed in a film of December, 1940 Admission to the Nova Scotia Sanatorium was advised The admission film of Feb 12, 1941, showed an irregular pneumothorax with 40 per cent collapse on the right side, but no cavity was seen On the left there was exudative productive disease extending from the apex to the third rib, with a cavity measuring 2¾ by 1¾ cm opposite the first rib and interspace A left sided thoracoplasty was carried out in three stages which were completed on April 8, 1941, seven ribs were removed The patient was in the fifth month of gestation at this time Convalescence was satisfactory and a cesarean section was performed on Aug 22, 1941 There were no complications to mother or child A film dated Dec 3, 1941, disclosed 30 to 40 per cent pneumothorax on the right and a satisfactory collapse due to thoracoplasty on the left Subsequent progress was satisfactory as evidenced by the fact that the patient was leading a normal life in September, 1950, nine years after the surgical procedure At the same time an x ray film dated Sept 15, 1950, showed no evidence of reactivation

CASE 3—F W, aged 28 years, was first admitted March 26, 1943, and remained until June 13, 1944 The history dated back to 1939 when this patient began to suffer from excessive fatigue and frequent colds In August, 1940, she developed right sided dry pleurisy following which a film was taken and tuberculosis disclosed She was admitted to a Cape Breton unit in November, 1940, where bilateral pneumothorax was instituted Admission film at the Nova Scotia Sanatorium, taken March 29, 1943, disclosed a bilateral pneumothorax with apparent closure of the cavity on the right, but a cavity 2 by 1¼ cm was seen opposite the first and second ribs (inner zones) on the left By May, 1943, the right lung had re expanded completely A three stage, six rib thoracoplasty was completed for the left lung on July 2, 1943, during the sixth month of gestation This patient was a primipara Severe cardiorespiratory collapse occurred immediately following the third stage of thoracoplasty, but otherwise postoperative convalescence was satisfactory Delivery of a healthy infant took place with the aid of midforceps on Sept. 18, 1943 By January, 1944, the cavity remained apparent in the underlying lung and measured 2¼ by 1¼ cm The patient was passed for a revision of the thoracoplasty However, she left for her home on June 13, 1944, and failed to return as planned, the last film was taken here on April 27, 1944

Subsequently she was readmitted on Dec 2, 1947, to a Cape Breton unit, and a film on Dec 8, 1947, revealed bilateral extension of disease with cavities measuring 5 by 4 cm on the right and 4 by 2 cm on the left side In March, 1948, the right upper lobe had become atelectatic while on the left there was no change On May 7, 1949, she was readmitted to the Nova Scotia Sanatorium where a film on May 10, 1949, revealed multipl cavitation in the right upper lobe as well as cavitation in the underlying lung on the left side Pneumoperitoneum was initiated on July 4, 1949, and has been continued to the present date Extensive courses of chemotherapy, including PAS, totaling 7,597 Gm, and 153 Gm of streptomycin have been administered Sputum, which was strongly positive on admission, has been negative on culture even since cessation of chemotherapy Bronchograms revealed advanced bilateral bronchiectasis The patient's general condition is excellent but, of course, the prognosis remains guarded [illegible] Indian patient. She was admitted on [illegible] Dec. [illegible], 1952. The admission film [illegible] on the right while there was [illegible] extending between the apex and [illegible] was carried out on [illegible] Postoperative progress was uneventful [illegible] and on December [illegible] her [illegible] at an early date.

[illegible] This patient was admitted on Aug. 30, [illegible] x-ray unit near her home she [illegible] pulmonary tuberculosis [illegible] Nova Scotia Sanatorium on [illegible] extending between the apex and second inter[illegible] nodular lesion extending [illegible] the first rib. The pro[illegible] On Oct. 28 and [illegible] removed on each [illegible] at the [illegible]

[illegible] sputum and fatigue [illegible] pulmonary tuberculosis. [illegible] June [illegible] 1949, to Nov. 18, 1950 [illegible] Church [illegible] on the right [illegible] interspace while on the [illegible] extended from [illegible] in the left [illegible] Aug. [illegible] 1949 [illegible] the fetal blood reaches one half that in the maternal blood stream, there have as yet been no reports of damage to the eighth nerve of the fetus, nor has there been in any of this series to date

SUMMARY

1 The histories of ten persons having had major chest surgery performed during pregnancy have been presented Five patients were subjected to thoracoplasty and five to pulmonary resection

2 It would appear that major collapse therapy or resectional surgery when indicated should be offered to the pregnant just as to the nonpregnant tuberculous woman

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Announcement

THE AMERICAN ASSOCIATION FOR THORACIC SURGERY

Notice of Annual Meeting

[illegible] meeting of the American Association for Thoracic Surgery will be [illegible] Montreal, Quebec, Canada. Headquarters will be at the [illegible] Hotel.

Requests for Hotel Reservations

[illegible] directly to the Reservation Manager, Sheraton Mount Royal Hotel, Montreal, Quebec, Canada. Please mention this Association, type of accommodation [illegible] hour of arrival. If accommodations are desired elsewhere, [illegible]

Thoracic Surgical Forum

[illegible] the Council has decided to try an experiment by assigning [illegible] Thoracic Surgical Forum for the presentation of short papers [illegible] instruments, surgical techniques, etc. Papers at this [illegible] to [illegible] the showing of lantern slides or [illegible] discussion of each paper [illegible] of The Journal of Thoracic [illegible]. If illustrated, an appropriate [illegible]

Abstracts for Papers

[illegible] including papers [illegible] otherwise they will [illegible]

Applications for Membership

[illegible]

Correspondence

To THE EDITOR

Some time ago, my attention was called to an article by Leslie J Temple, F R C S, of Liverpool, England, which appeared in THE JOURNAL OF THORACIC SURGERY 19 142 (March) 1950 The article is entitled, "Aneurysm of the First Part of the Left Subclavian Artery" In his report, the author states that during the course of an operation for subclavian aneurysm, he performed transpleural ligation of the first portion of the left subclavian artery He also mentions an unpublished case of Mr H Morriston Davies in which a similar procedure was performed in June 1944 At one point, Mr Temple states as follows "As I have pointed out, apart from Morriston Davies' unpublished case, I know of no direct transpleural approach to the left subclavian artery"

For the benefit of those who may wish to collect a set of references dealing with intrapleural ligation of the first portion of the left subclavian artery, may I call attention to an article of mine entitled, "Transpleural Transthoracic Ligation of the First Portion of the Left Subclavian Artery" which appeared in *Surgery* 10 747 (November) 1941 In my article, transpleural ligation of the first portion of the left subclavian artery was performed as a preliminary to mid humeral amputation, in a case of congenital, multiple, arteriovenous communications involving the left upper extremity To the best of my knowledge, my case was the first in which the basic principle of the intrapleural subclavian artery ligation was performed

ARTHUR S W TOUROFF, M D

The Journal of Thoracic Surgery

[illegible] April, 1954 No. 4

Original Communications

CARDIOSCOPY, SIMPLE AND PRACTICAL

[illegible] Charles P. Bailey, M.D.,* [illegible], M.D.,** and William [illegible]***

Philadelphia, Pa.

[illegible] surgery has been our [illegible] interest on the [illegible]. Several cardioscopes have [illegible] simple and efficient instrument for such [illegible]

THE [illegible] CARDIOSCOPE

[illegible] solid rod of Lucite (methyl [illegible] has been shaped to the desired design by [illegible] careful polish [illegible] to the highest degree of efficiency of [illegible]

[illegible] addition [illegible] This [illegible] cardioscopes. The [illegible] proved awkward in handling A groove is placed at the proximal end of the cardioscope in alignment with the longer end of the obliquity of the distal end of the scope (Fig 1, A and B)

The cardioscope may be designed to produce some degree of magnification by making the proximal end slightly convex

The cardioscope has been designed in a variety of sizes in order that any situation may be dealt with when the necessity for variable sizes is required

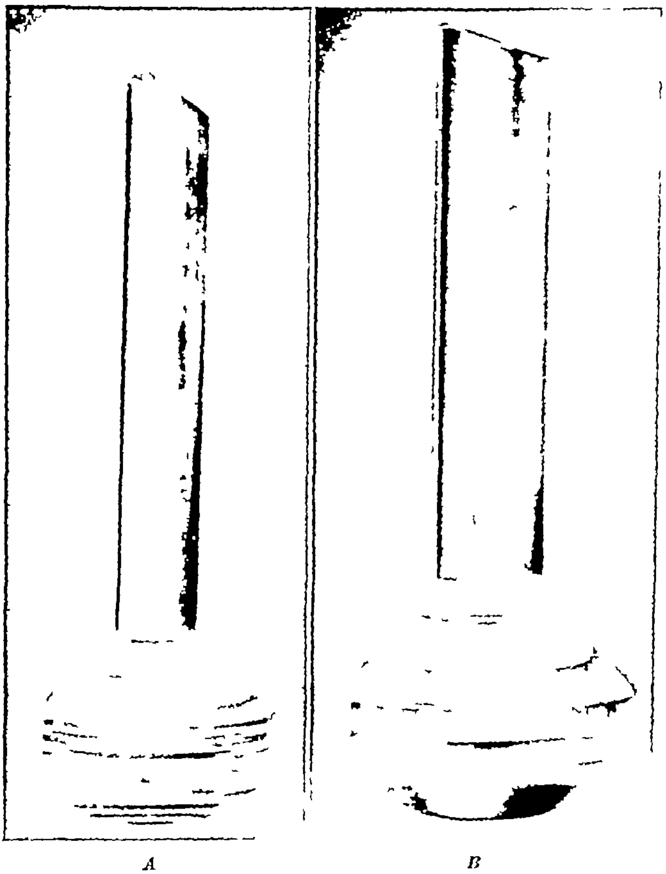
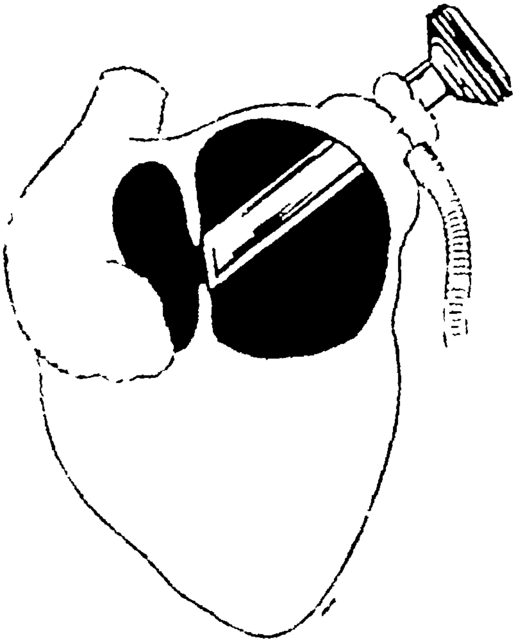


Fig 1 — A Photograph of the Bolton cardioscope showing the oblique distal end uppermost and the expanded proximal end Two grooves encircling the proximal end facilitate handling *B* A larger instrument which may be used to examine interatrial septal defects where there is a very large or redundant right auricle

USES OF THE CARDIOSCOPE

Interatrial Septal Defect—Perhaps the most significant use of the cardioscope is in the inspection of the interatrial septum (Fig 2) The proper technical repair of an atrial septal defect may depend upon a satisfactory appreciation of the defect to be repaired The tactile sense has been the best method for orientation* however, when visualization of the outline of the septal [illegible] ability adds greatly to the orientation necessary for re- [illegible]. Dual defects of this septum are not uncommon and some [illegible] by digital exploration.

[illegible] — Anomalous pulmonary veins are not an uncommon [illegible]. An associated interatrial septal defect usually co- [illegible]. The [illegible] of these defects is variable and we have encountered instances [illegible] small.



[illegible]

made (Fig 3) and the row of sutures placed during atrio septo pexy are placed peripheral to the extent of incision, thereby shunting the blood from the lungs into the left atrium (Fig 4)

Visualization of the Heart Valves—We have encountered valve leaflet defects prior to our use of the cardioscope where observation of the defect would have been extremely useful, for example, a congenital perforation of the septal leaflet of the mitral valve

Visualization of the Interventricular Septum—We have not had occasion to use the cardioscope in the human heart to examine the interventricular septum, however, the ventricular septum has been completely visualized in the animal laboratory

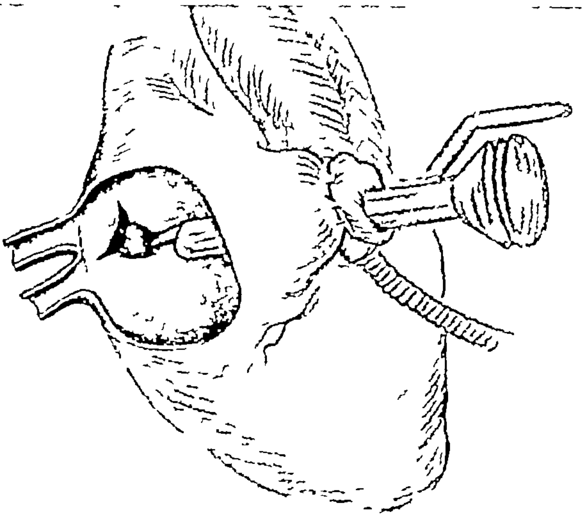


Fig 3

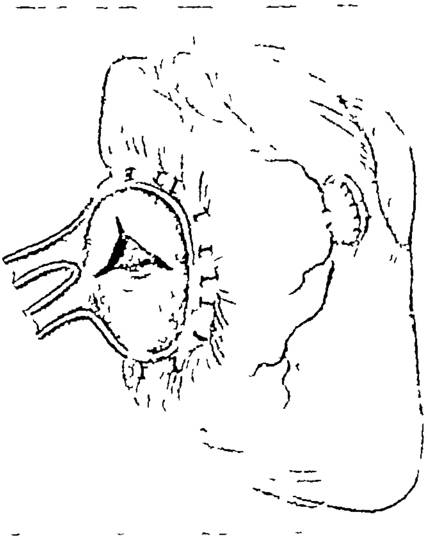


Fig 4

Fig 3—Cardioscope through right atrial appendage with knife protruded radial incisions in septal defect anomalous pulmonary veins entering adjacent to defect

Fig 4—Atrio septo pexy suturing wall of atrium to edges of enlarged defect, thus shunting blood from right lung into left atrium and closing septal defect

The surgical treatment of ventricular septal defects has always been fraught with difficulty because of variation in the amount of "overriding of the aorta" For example, differentiating between the Eisenmenger complex, high ventricular septal defect, and Maladie de Roger may be difficult In such cases, the surgical attack may be profoundly altered or guided by the location of the ventricular defect and its relation to the position of the aorta Closure of the defect may be entirely precluded by a left ventricular outflow tract which would be severely obstructed by the methods of repair which are at our command today[10] Likewise, visualization of the size of the ventricular septal defect is helpful in deciding upon the type of repair of the defect

Infundibular Pulmonary Stenosis—Treatment of infundibular stenosis always presents the problem of 'how much of the infundibulum should be re [illegible] Appreciation of the amount of obstruction created by an infundibular [illegible] ventricular crista is greatly facilitated by an estimation of the [illegible] If the Brock procedure is to be performed a quantitative [illegible] amount of tissue to be excised is most helpful

[illegible] *the Animal Laboratory*.—In the animal laboratory we have been able [illegible] valves of the heart and all valves. By inserting a small cardio- [illegible] ventricle near the apex it may be advanced along the out- [illegible] the aortic valve cusps may be viewed. We have also [illegible] the coronary artery orifices by approaching the aortic valve [illegible] in the aortic arch.

[illegible] Through the Cardioscope.—We have found photographs [illegible] possible but difficult because of the motion of the heart. [illegible] we have been able to get a satisfactory photograph [illegible] in about 50 per cent of the attempts. Attempts [illegible] cinematographic studies of movements of the mitral [illegible]

[illegible]

and the structure The instrument is then moved about in a systematic fashion to outline the edge of the defect or structure (Fig 2) One must use the same precautions concerning obstructing the flow of blood as in any intra cardiac procedure The valves may not be occluded for longer than three heart beats

During inspection of the interatrial septum, there is minimal obstruction to the flow of blood

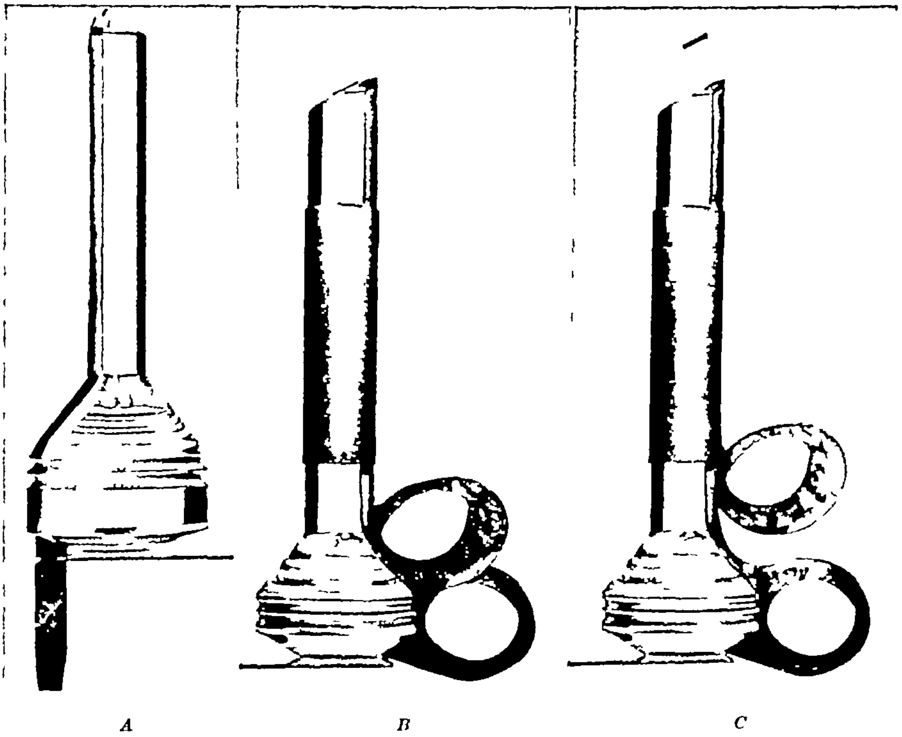


Fig 6—*A* Operating attachment (Gemeinhardt) with knife protruding from end of scope This may be completely retracted or extended for 1 cm A rubber sheath is used as in *B* and *C* *B* and *C* Guillotine knife inserted in a groove A thin rubber sheath applied to shaft diminishes blood loss along groove for knife. Knife open (*C*) and closed (*B*)

Introduction of the cardioscope into the ventricle is through the wall at a level as near the apex as possible (Fig 5) A heavy purse string suture of braided silk is first placed deep in the ventricular musculature and the circle of the purse-string is made about twice the diameter of the proposed incision for insertion of the cardioscope Secure hemostasis is thus provided An incision of desired length is made and finger pressure controls bleeding until the scope is inserted A cardioscope of smaller diameter is preferable for use in the ventricle because it necessitates a smaller repair of the myocardium After the inspection is completed and the instrument is withdrawn, the incision is closed by two or three fine cotton sutures and the purse string is removed, or definitive surgery performed [illegible] W[illegible] has devised attachments which are useful in the animal [illegible] unlimited find many uses in the human heart. These at[illegible] useful in creating septal defects and valvular defects and in [illegible] chordae tendineae or papillary muscles. One attachment consists of a [illegible] which is projected from the distal end of the cardioscope for [illegible] and another is a guillotine type of knife for division of any [illegible] edge (Fig. 6, B and C).

CONCLUSION

We have presented a cardioscope which is simple and practical for use in [illegible] for the experimental laboratory animal.

[illegible] into the heart with the same ease as an exploring finger.

[illegible] in the transmission of light only the [illegible] light is necessary.

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COMPLICATIONS ASSOCIATED WITH RESECTIVE OPERATIONS FOR PULMONARY TUBERCULOSIS

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IN RECENT years two things which have had a profound effect on the treatment of tuberculosis are (1) the discovery and use of chemotherapeutic agents, and (2) the advances in thoracic surgery, physiology, and pathology. Our experiences with resective operations for tuberculosis prior to the use of streptomycin and to the advances in thoracic surgery serve to echo the experiences of other workers such as Sweet,[1] who has stated that his experiences have led him to conclude "that extirpative surgery is a procedure of limited usefulness in the management of the disease" and of Overholt and associates, who have stated that the statistics of four or five years ago are now of historical interest only.

This study has been undertaken to examine our present and past experiences and, if possible, to utilize such analysis for the improvement of our future work. The place of resective operations will be determined by evaluation of (1) the risk involved in undergoing the operative procedures and (2) the late follow-up of patients who have undergone resective procedures. Since most of our experience with these operations has been acquired within the past two years it is too early to make a significant study of the latter factor. A study of the risk and complications of these operative procedures, however, seems warranted.

MATERIAL

Approximately 120 resections for pulmonary tuberculosis have now been done at Nopeming Sanatorium. However, in order to have a follow-up study of at least three months' duration for all patients, only those who underwent resections through Dec. 9, 1952, were included in this study. This period includes both the prestreptomycin era and the subsequent period. The study is based on a total of 110 surgical resections performed on 98 patients. The actual operations were done by seven different thoracic surgeons so that the results obtained represent a good cross section of results of different techniques of resection. Pneumonectomy was performed in 20 cases, lobectomy or bilobectomy in 30 cases, segmental resection in 44 cases, local excision or subsegmental resections in 10 cases, and combined segmental resection and subsegmental or local excision in 6 cases. For the purpose of analysis the last three procedures will be considered together.

In all cases operations were done with the patient under general anesthesia. In some cases local anesthesia was used in combination with general anesthesia

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[illegible] in various positions when operated on including the prone [illegible] semiprone. This factor has been analyzed.

[illegible] program has included close attention to intake and output [illegible] in regard to intravenous administrations of fluid [illegible] of blood immediately after operation. By means of a portable [illegible] roentgenograms of the thorax were taken daily for the first few days [illegible] well stabilized with all drainage tubes removed. Aspiration [illegible] to remove blood, fluid or air and bronchoscopy to remove [illegible] were procedures used freely to maintain a smooth postopera[illegible]

RESULTS OF ANALYSIS

[illegible] men and [illegible] women in this series. The oldest patient was 57 [illegible] youngest 18 years. The majority of patients were 30 to 40 [illegible]. The patients underwent resections who had never received [illegible] as part of their postoperative course. The [illegible] done on patients who had received streptomycin [illegible] suffered from complications. A study of the complica[illegible] could be divided into those due to tuberculosis and [illegible] procedures (Table I).

[illegible] CASES OF PULMONARY TUBERCULOSIS

	TIMES OCCURRED
[illegible] (patients)	
[illegible]	5
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	6
[illegible]	1
[illegible]	[illegible]
[illegible]	11
[illegible]	1
[illegible]	1
[illegible]	1
[illegible]	1
[illegible]	1
[illegible]	1
[illegible]	1
[illegible]	1

[illegible]

TABLE II COMPLICATIONS WHICH FOLLOWED PNEUMONECTOMY, LOBECTOMY, AND SEGMENTAL RESECTION

	CASES
After pneumonectomy (18 patients)	
Surgical shock with cerebral infarction, recovery	1
Surgical shock with death	3
Contralateral exacerbation	1
Contralateral reactivation with stump bronchitis	1
Bronchopleural fistula with contralateral spread	1
Tuberculous empyema with infection of wound	1
Bronchopleural fistula	1
Stump bronchitis	2
Nontuberculous empyema with pleurocutaneous fistula	1
Atelectasis	1
After lobectomy (14 patients)	
Mediastinal and subcutaneous emphysema, reaction to transfusion, pneumonia, ileus, death	1
Stump bronchitis	2
Stump bronchitis, bronchopleural fistula	1
Atelectasis	3
Ipsilateral and contralateral spread, stump bronchitis	1
Cardiac decompensation	1
Bronchopleural fistula with ipsilateral and contralateral spread	1
Ruptured gastric ulcer with peritonitis, atelectasis	1
Guillain Barré syndrome with death	1
Atelectasis, stump bronchitis	1
Ipsilateral reactivation	1
Bronchopleural fistula with empyema (nontuberculous)	1
After segmental or local resection (16 patients)	
Bronchopleural fistula without empyema	1
Bronchopleural fistula with empyema	2 (1 tubercular [?]) (1 nontubercular)
Atelectasis	4
Persistent pneumothorax pocket	10
Severe postoperative hemorrhage	1

and were in most cases more seriously ill. Table II lists the complications which occurred in relation to the procedure performed.

A few years ago Overholt and his group[7] introduced the use of the face down or prone position in thoracic surgery primarily as a method to avoid contralateral spread of disease. Its main advantage, particularly concerning patients with positive secretions, is said to be the drainage of secretions into the trachea and out of the mouth instead of into the contralateral lung. It also is maintained that ventilation of the lungs is better and, consequently, less carbon dioxide is retained than when the patient is in the lateral position. The exponents of the lateral position maintain that the incidence of contralateral spread and similar complications is not any greater provided adequate clearance of the tracheobronchial tree is maintained during surgical intervention.

In our series of cases complications developed among 29 of 68 patients who were in the prone position when operated on, a complication rate of 41 per cent. Complications developed in 15 of 24 patients who were in the lateral position when operation was performed or a complication rate of 63 per cent. The one patient who underwent operation in the supine position had a complication postoperatively. The significance of these figures may reasonably be challenged as the operations performed on patients in the lateral position were [illegible] earlier part of our experience and some did not have the [illegible] and none had the benefit of our increased experience [illegible] At the time of this report we were using the prone [illegible]ly.

[illegible] afforded a means by which we can produce a gross [illegible] reduction in the amount of tracheobronchial secretions [illegible] high percentage of cases. The importance of producing [illegible] prior to operation if possible is demonstrated by contrasting [illegible] complications of the group of patients who had grossly [illegible] at the time of operation with that of the group whose sputum [illegible] and culture at the time of operation. Of 14 pa[illegible] due to tuberculosis 10 had positive sputum at the [illegible] 4 had negative sputum by concentrate and culture.

T[illegible] thoracoplasty performed before, with or immediately after [illegible] to analyze because of other factors such as extent [illegible] in surgical techniques. Considering only compli[illegible] found that 9 of 31 patients, or 29 per cent, who [illegible] with thoracoplasty had complications, and that 6 of [illegible] or 12 per cent, who had undergone resections without thoracoplasty [illegible] We are of the opinion that these figures misrepresent the [illegible] in association with surgical measures because most of [illegible] thoracoplasty and resection followed by complications [illegible] operations early in the period covered by our study [illegible] more extensive disease. The recent report of the Vet[illegible] 25 per cent of the patients who had lobectomies [illegible] thoracoplasty had complications, and that only [illegible] lobectomies with both thoracoplasty and chemo[illegible]

[illegible] months after resection. Three [illegible] of them died as a result of surgical [illegible] bronchopleural fistula with [illegible] had been removed and [illegible] had the upper lobe [illegible] right lung Death in this case occurred seven years postoperatively and was attributed to hypertensive cardiovascular disease

The postoperative mortality rate is, therefore, 6 4 per cent Including the three late deaths the total mortality rate of the group is 9 1 per cent

The importance of the use of chemotherapy and its effect on patients who submit to operations for tuberculosis cannot be overemphasized The reduction in the number of complications associated with resections performed for tuberculosis is evident in our group of cases and is summarized in Table III

TABLE III RELATION OF CHEMOTHERAPY TO COMPLICATIONS AND DEATH OF TUBERCULOUS PATIENTS WHO UNDERWENT RESECTION

		PERCENTAGE OF PATIENTS				
		COMPLICATIONS		DEATHS		
OPERATION	NO OF PATIENTS	ALL TYPES	TUBERCULOUS TYPE	OWING TO TUBERCULOSIS	OTHER CAUSES	TOTAL
Pneumonectomy						
Before chemotherapy	6	83	50	16	16	32
After chemotherapy	14	50	28	0	14	14
Lobectomy						
Before chemotherapy	2	100	100	0	0	0
After chemotherapy	26	42	19	0	10	10
Segmental resection						
Before chemotherapy	1	100	100	0	0	0
After chemotherapy	60	25	0	0	0	0
Resection (all types)						
Before chemotherapy	10	90	60	10	10	20
After chemotherapy	100	33	10	0	5	5

COMMENT

It has been our experience that the morbidity and mortality rates in cases of tuberculosis in which resective operations have been performed have been greatly reduced since the advent of chemotherapy In fact, before chemotherapy, resective operations for tuberculosis were dangerous but often necessary in many cases Our experience, however, with resections prior to the use of chemotherapy was so small that our figures were not representative of the situation Our experience since chemotherapy, particularly with segmental resection, has been more gratifying and we are of the opinion that our figures compare favorably with those of others Although 25 per cent of our patients who had segmental resection had complications, it must be remembered that most of the complications noted were of a transient nature and were easily remedied by therapeutic measures

Little information has been included in the literature concerning the postoperative pneumothoracic space, particularly after resection for tuberculosis Hence it is interesting to note 10 cases in our series in which the patients had such a space after undergoing segmental resection The lungs of 8 of the 10 patients re expanded spontaneously and the space disappeared without further surgical procedure Aspiration was carried out in several instances, but it was noted that aspiration itself did not produce significant re expansion of the lung and disappearance of the space In the 8 cases in which there was spontaneous [illegible] space 5 patients had spontaneous obliteration [illegible] and the remaining 3 had obliteration in [illegible] The other 2 patients had a space of sufficient size that [illegible] should be done accordingly in each a four rib [illegible] resulted in obliteration of the space. In [illegible] tuberculosis developed. Thus it appears from [illegible] resection for tuberculosis the re[illegible] expand spontaneously, the space created be[illegible] will be obliterated without any significant danger from [illegible] obliteration will occur within a few months.

[illegible] in selected cases is a safe, rational opera[illegible] methods of surgery, anesthesia and post[illegible] tuberculosis are being operated on earlier [illegible] and thereby tissue and function of [illegible] resection is a procedure which adapts [illegible]

[illegible]

[illegible] results of resection operations in treatment of [illegible] several years. Hence this study is con[illegible] procedures in 110 resections done on

[illegible] produced a profound reduction in the risk [illegible] which in most [illegible] will be the rate of complications [illegible] is to be lower among those patients [illegible] due to tuberculosis were [illegible] and

[illegible] resection did not [illegible] with [illegible] findings

COMPARATIVE STUDY OF PULMONARY FUNCTION LOSS THORACOPLASTY VERSUS SMALL RESECTION IN SURGERY OF TUBERCULOSIS

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MILWAUKEE, WIS

THE GRADUAL increase in resective surgery for pulmonary tuberculosis stimulated our interest five years ago to determine the comparative effects of thoracoplasty in contrast to small resections on the loss of pulmonary function in patients surgically treated for tuberculosis Seventy one patients were studied with respiratory function tests before and after surgery between January, 1948, and December, 1952, in an effort to further delineate this question

Posterior staged thoracoplasties were performed on twenty four of these patients, and forty-seven had small resective surgery of a segmental subsegmental, or wedge nature Among the group of thoracoplasty patients eighteen had their operations as primary forms of surgical therapy, and six of the patients had had phreniclasia performed at least eighteen months prior to their thoracoplasty All of the thoracoplasties were posterior operations with preservation of relatively long anterior rib segments below the first rib four patients had five ribs removed, and twenty had six ribs resected

In the resection group, there were twenty patients who had segmental resection and twenty-seven who had subsegmental or wedge resection A breakdown of the segmental resection group reveals the following loss of segments 12 patients—1 segment, 7 patients—2 segments, and 1 patient—3 segments In the subsegmental and wedge resection group, the number of wedges removed varied from one to twelve 20 patients had 1 to 3 wedges resected, 6 had 4 to 8, and 1 had 12 wedges resected

METHOD OF STUDY

The patients studied were men whose ages ranged from 22 to 60 years Prior to surgery, ventilatory tests included determination of pulmonary volumina, maximum breathing capacity, and walking ventilation, the majority also had bronchospirometry Function determinations were made within a period of two weeks before surgery The same studies were repeated postsurgery, the interval being approximately six months for thoracoplasty and three months for resection A six month interval was arbitrarily selected for thoracoplasty cases to assure adequate return of function In resection, trauma and musculoskeletal dysfunction were minimal and recovery was rapid, permitting repetition of tests at the three month interval Also, patients undergoing bilateral excisional surgery were considered ready for surgery on the contralateral lung after three months, thereby necessitating study at that

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[illegible]

[illegible] useful results [illegible] few were [illegible] the figures were usually [illegible] This the problem [illegible] Major consideration [illegible] capacity of the lung [illegible]

[illegible] breathing capacity. Each patient [illegible] Compared [illegible] progression [illegible] The walking ventilation [illegible] The patient walks 200 feet in two [illegible] The quantity of gas [illegible] recorded as liters per

[illegible] either or [illegible] bronchial [illegible] Preliminary sedation [illegible] morphine [illegible] position of the catheter in the left [illegible] proximal [illegible] 100 per cent oxygen [illegible] respiratory [illegible] Bronchoscopy [illegible]

RESULTS

[illegible] I, II [illegible] III [illegible] and illustrate loss of pulmonary [illegible] and wedge resection respectively [illegible] are limited to the oper[illegible] was to measure loss in oxygen [illegible] lung. The figures listed under [illegible] pulmonary [illegible] ventilation column [illegible] surgery. The ratio [illegible] listed [illegible] In [illegible] did this

[illegible] I, II [illegible] III [illegible]

[illegible] I [illegible] III [illegible]

TABLE I LOSS OF PULMONARY FUNCTION WITH SMALL THORACOPLASTY

CASE NO.	AGE	SIDE AND RIBS	BRONCHOSPIROMETRY BEFORE O_2%	AFTER O_2%	LOSS O_2%	BEFORE V C %	AFTER V C %	LOSS V C %	SPIROMETRY BEFORE V C (C.C.)	AFTER V C (C.C.)	LOSS V C %	M B C BEFORE	AFTER	LOSS L	LOSS %	W V CHANGE L.
1	30	R 5	58	48	10	53	50	3	4450	3320	25	132	150	+18	+14	−1 5
2	55	L 5	55	30	25	39	42	+3	3195	2843	11	89	78	−11	−12	+0 2
3	30	R 5	38	36	2	47	43	4	4067	3964	2	124	102	−22	−18	−2 6
4	59	L 5	—	—	—	—	—	—	3154	2428	23	124	107	−17	−14	−1 5
5	25	R 6	—	—	—	—	—	—	3440	2469	28	82	67	−15	−18	—
6	50	L 6	—	—	—	—	—	—	3112	2697	13	129	99	−30	−23	−3 7
7	38	R 6	—	—	—	—	—	—	4512	3517	22	160	138	−22	−13	−2 2
8	56	R 6	48	35	13	50	39	11	3610	2303	36	75	73	−2	−3	+1 6
9	24	L 6	33	35	+2	42	34	8	4056	2739	32	129	129	0	0	—
10	28	L 6	—	—	—	—	—	—	4710	3433	27	161	158	−3	−2	−1 3
11	29	R 6	51	41	10	46	42	4	4544	3237	29	110	97	−13	−12	+1 1
12	24	R 6	65	47	18	59	43	16	4108	3039	26	103	105	+2	+2	−1 8
13	26	R 6	48	42	6	53	51	2	4980	3745	25	140	124	−16	−12	+1 8
14	34	R 6	62	25	37	67	30	37	4606	3009	35	125	94	−31	−25	−3 4
15	24	R 6	47	45	2	60	44	16	3486	2552	27	121	81	−40	−33	−3 9
16	27	L 6	50	50	0	56	38	18	5498	4710	14	118	124	+6	+5	−1 0
17	41	R 6	—	—	—	—	—	—	3859	2677	31	130	94	−36	−28	+0 9
18	33	R 6	47	38	9	53	46	7	4440	2614	41	125	107	−18	−14	+2 7
19	32	R 6	64	33	31	—	—	—	4814	2988	38	141	131	−10	−7	+5 2
20	27	R 6	60	55	5	—	—	—	3400	2469	27	121	115	−6	−5	—
21	44	R 6	48	47	1	—	—	—	5395	3652	32	149	132	−17	−11	—
22	30	R 6	48	36	12	53	50	3	3569	2541	29	107	94	−13	−12	+0 4
23	36	R 6	37	36	1	39	37	2	2179	1950	10	75	70	−5	−7	—
24	30	L 6	—	—	—	—	—	—	4067	2926	28	118	91	−27	−23	+1 0

TABLE III. LOSS OF PULMONARY FUNCTION WITH SUBSEGMENTAL AND WEDGE RESECTION

CASE NO.	AGE	NO. WEDGES	BRONCHOSPIROMETRY						SPIROMETRY			M.B.C.				W.V. CHANGE L.
			BEFORE O₂%	AFTER O₂%	LOSS O₂%	BEFORE V.C.%	AFTER V.C.%	LOSS V.C.%	BEFORE V.C. (C.C.)	AFTER V.C. (C.C.)	LOSS V.C.%	BEFORE	AFTER	LOSS L.	LOSS %	
1	57	1	51	48	−3	56	50	6	2915	2739	6	83	81	−2	−2	+2.2
2	40	1	45	47	+2	45	41	4	4918	4731	4	129	129	0	0	−0.5
3	40	2	53	51	−2	59	54	5	4731	4606	3	129	124	−5	−4	0
4	32	1	55	43	−12	53	42	11	4482	3590	20	122	130	+8	+6	+3.2
5	28	2	50	51	+1	—	—	—	4150	3942	5	132	134	+2	+1	+1.0
6	50	3	48	51	+3	50	42	8	5268	4627	12	167	137	−30	−18	−2.0
7	48	3	—	—	—	—	—	—	4046	4046	0	124	102	−22	−18	+0.9
8	24	8	44	38	−6	50	43	7	5187	4959	4	156	148	−8	−6	+0.7
9	40	8	54	53	−1	58	54	4	4191	3652	13	105	110	+5	+5	0
10	24	3	48	47	−1	46	46	0	3558	3590	+1	142	150	+8	+6	+1.8
11	24	5	50	41	−9	51	38	13	5146	3922	24	198	182	−16	−8	+1.7
12*	32	1	47	38	−9	51	43	8	4896	4357	11	118	142	+24	+20	0
13	58	1	52	50	−2	52	49	3	3880	3735	4	81	81	0	0	0
14	31	12	37	32	−5	33	29	4	3569	2520	29	110	94	−16	−14	—
15	29	2	46	43	−3	47	42	5	5125	4772	7	172	166	−6	−3	−2.1
16	57	2	56	48	−8	62	51	9	3485	3361	3	—	—	—	—	−2.6
17*	20	2	41	29	−12	40	29	11	4233	3859	9	115	134	+19	+16	−1.7
18	40	3	56	56	0	58	59	+1	5084	4648	4	162	174	+12	+7	−2.2
19	28	4	63	56	−7	64	56	8	3320	3195	4	113	113	0	0	−0.5
20	28	3	—	—	—	—	—	—	4337	4088	8	161	148	−13	−8	+0.5
21*	23	4	—	—	—	—	—	—	5001	4886	2	164	183	+19	+11	+1.5
22	31	3	44	32	−12	40	27	13	3569	3029	15	156	145	−11	−7	−2.6
23	31	7	48	48	0	38	36	2	4274	4191	2	156	161	+5	+3	+1.2
24	40	1	47	44	−3	46	42	4	4046	4171	3	111	114	+3	+2	−2.4
25	28	3	47	44	−3	46	37	9	3652	3258	11	110	98	−12	−11	−0.8
26*	28	2	46	38	−8	45	41	4	4980	4390	12	188	212	+24	+12.7	—
27	27	3	51	49	−2	53	49	4	4005	3682	8	137	118	−19	−14	—

*Postsurgical M.B.C. increased 10 per cent or more.

[illegible] represents no measurable loss [illegible] depend upon complete [illegible] cooperation [illegible] in spite of [illegible] reassurance are reluctant to [illegible] surgery. After surgery there [illegible] (2) improvement in [illegible] and (3) the manual lift [illegible] Thus [illegible] affected by surgery. [illegible] maximum [illegible] segmented and four [illegible] II and III [illegible] postoperatively exceeded their pre- [illegible] 11 to 40 [illegible] These figures were [illegible] MBC Table IV [illegible] believed the [illegible] cooperation prior [illegible] would [illegible] Of the patients [illegible] adherent [illegible] function loss

[illegible]

walking ventilation following surgery were +5.2 L and -3.9 L The great majority of patients approximated the presurgical test figure within 3 L No definite postsurgical trend toward decrease or increase of walking ventilation was noted

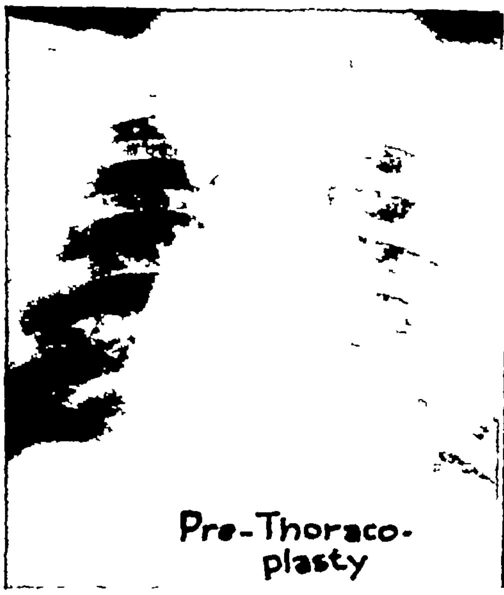


Fig 1

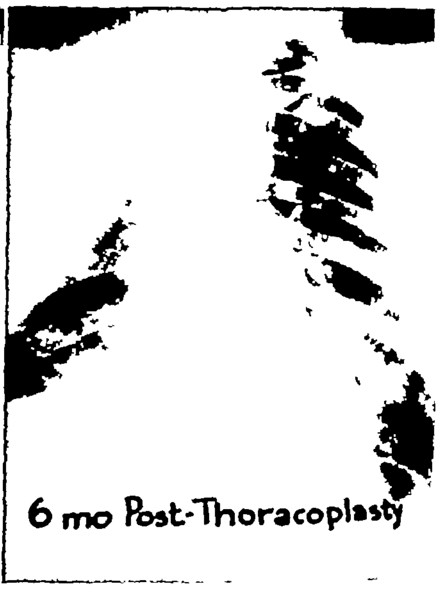


Fig 2

Fig 1—(Case History I) This 34 year-old white man was admitted August 1950 with moderately advanced tuberculosis the right apex contained a 2 cm cavity Pulmonary function prethoracoplasty was normal

Fig 2—(Case History I) Two stage six-rib thoracoplasty was performed in November and December 1950 complicated by pleural tear and effusion X-ray view taken six months after surgery reveals moderate scoliosis Diaphragm adherent laterally with limited motion Pulmonary function diminished significantly

Table V is a composite of the patients having bronchospirometry before and after surgery, it illustrates loss of oxygen consumption and vital capacity for the operated lung, expressed as mean percentages Oxygen consumption diminished as follows Thoracoplasty—10.6 per cent, wedge—4.4 per cent segmental—2.6 per cent Vital capacity of the operated lung was reduced Thoracoplasty—9.2 per cent, wedge—6.2 per cent, and segmental—4.4 per cent A significantly greater functional loss occurs in thoracoplasty where total vital capacity is diminished 25.4 per cent and vital capacity of the operated lung only 9.2 per cent, indicating that musculoskeletal dysfunction produced by thoracoplasty restricts movement of the entire thorax

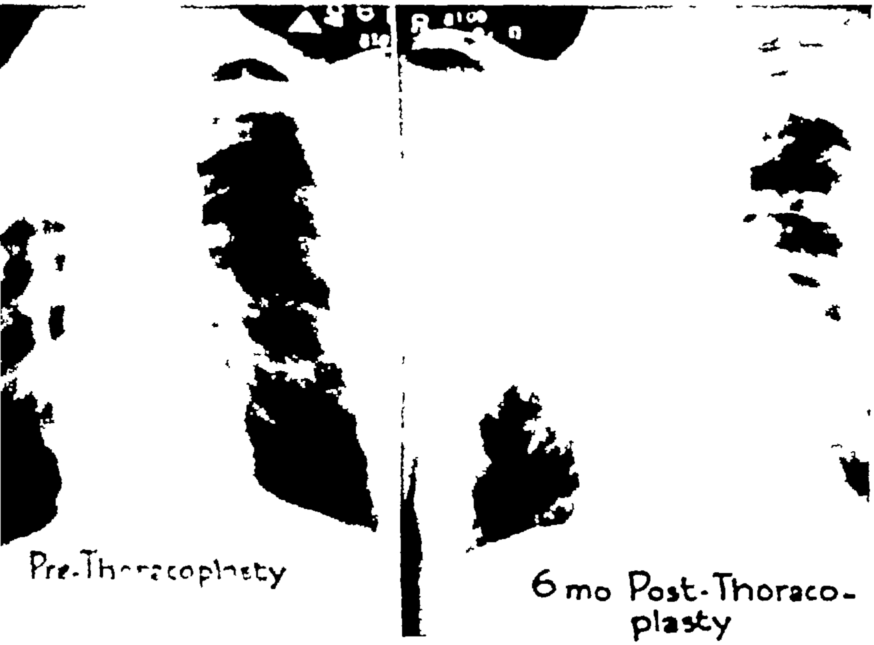
INDIVIDUAL CASE STUDIES

Four case histories, two thoracoplasty and two resection are briefly presented with x ray pictures to illustrate that pulmonary function loss may vary widely Complications may contribute significantly to function loss

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	% LOSS VC
[illegible]	17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible] (percentage [illegible] the mean)



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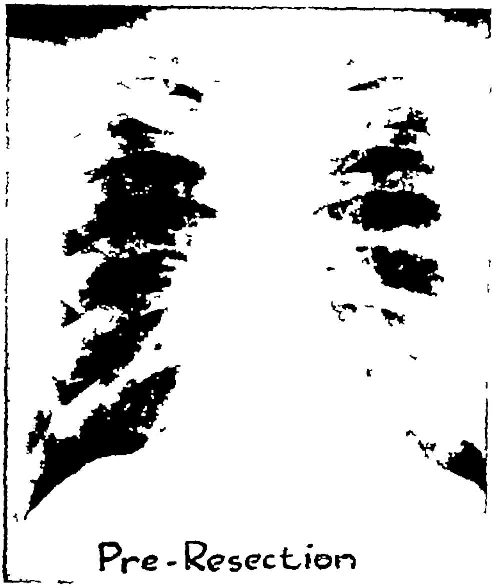
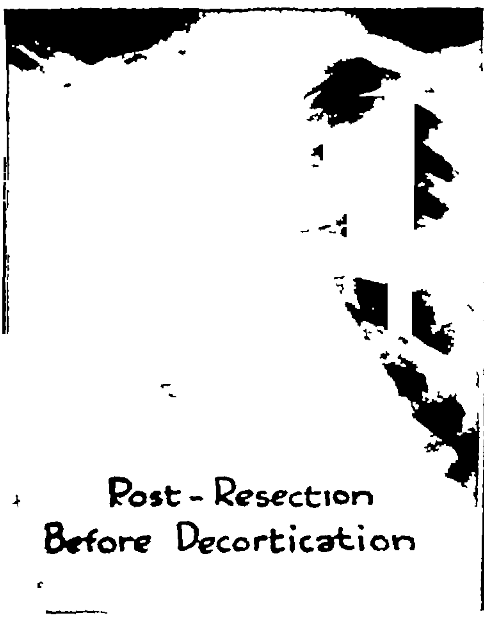


Fig 5



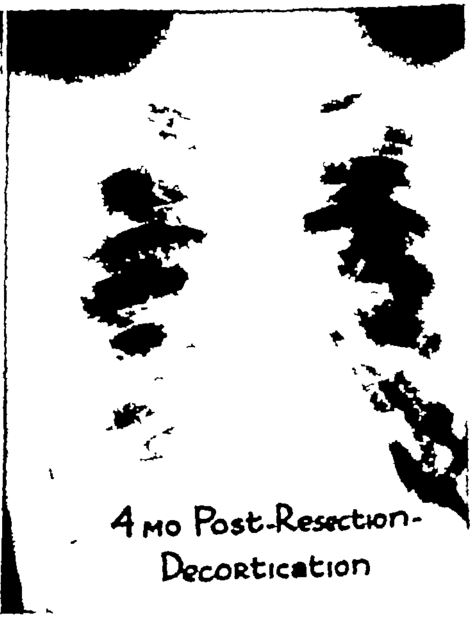


Fig 6

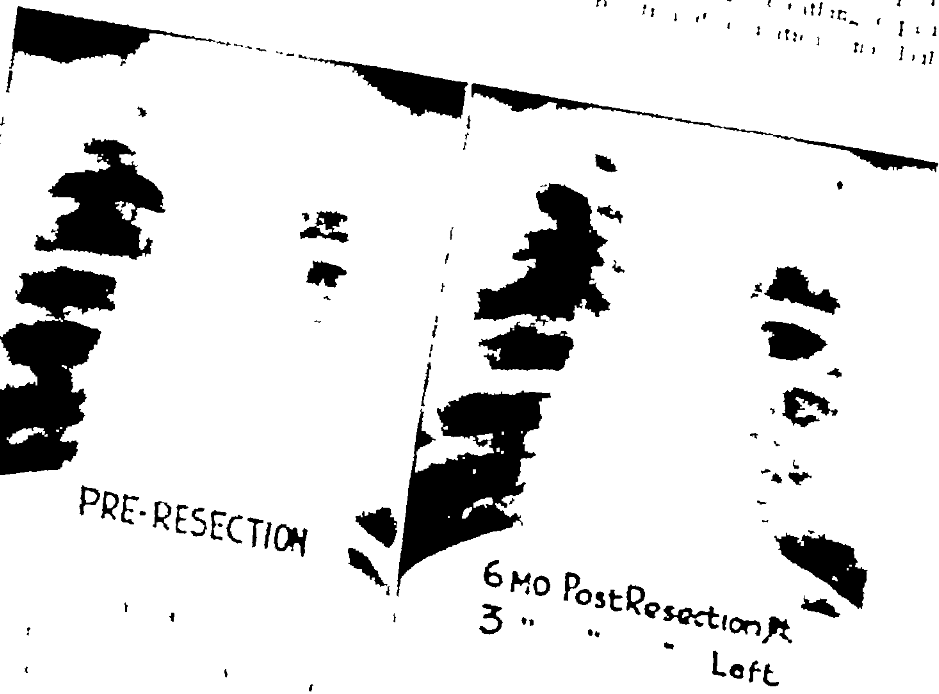
Fig 7

Fig 5—(Case History III) A 24 year old white man was admitted in 1952 with moderately advanced pulmonary tuberculosis of the right upper lobe He was treated for four months prior to resection with daily streptomycin and PAS (retreatment) X ray stability has occurred with no open cavity Presurgical pulmonary function was excellent.

Fig 6—(Case History III) X-ray view taken eleven days after resection Five wedges (caseous tuberculosis) resected from right upper lobe on April 10 1952 Hemothorax followed the patient's condition not improved by Varidase and aspiration Decortication twelfth postoperative day with bronchial leak and slow re-expansion of right lung

Fig 7—(Case History III) Four months after wedge resection and decortication Motion of right diaphragm impaired slightly Significant function loss prevented by decortication

[illegible]


PRE-RESECTION
6 MO PostResection Rt
3 " " " Left

DISCUSSION

The effect of thoracoplasty on pulmonary function has been adequately studied, but little has been published regarding functional alteration with small resection Kaltreider[6] commented that thoracoplasty produces a greater reduction in the vital capacity than is to be expected from the extent of lung tissue compressed He noted a 50 per cent reduction in the predicted normal value of vital capacity (based on height) in individuals with only five-, six-, or seven rib thoracoplasty, and as an explanation he stated that thoracoplasty interferes with the mechanics of respiration by reducing the lateral expansion of the chest, excursion of the diaphragm and rib rotation

Lerner[7] noted that following thoracoplasty, total pulmonary volume is diminished, reserve air showing the greatest reduction In nine six rib thoracoplasties he noted an average maximum breathing capacity loss of 14 per cent and an average vital capacity loss of 24 per cent After a six-rib thoracoplasty, the oxygen intake showed a tendency to decrease and the vital capacity decreased in all cases on the thoracoplasty side Warring[3] studied twenty six thoracoplasties (majority eight ribs or more) and noted lowering of the maximum breathing capacity in twenty-five cases, in a few as much as 30 to 40 L In only five patients did walking ventilation change 5 L or more following thoracoplasty

Cournand and Richards[8] noted no consistent correlation between the number of ribs resected and the decrease in maximum breathing capacity Important factors disturbing such a correlation in individual cases were the development of scoliosis, further disturbance in diaphragmatic function or collapse of variable amounts of normal lung tissue Gaubatz, cited by Cournand,[8] studied 200 cases and concluded that an apical thoracoplasty decreases maximum breathing capacity up to 15 per cent of its preoperative value

At variance with these opinions, Wright and Woodruff,[9] on the basis of twenty-five thoracoplasties, concluded that when collapse is confined to diseased lung tissue, no significant reduction in respiratory capacity on the surgical side occurs They stated that after sufficient time had elapsed for return of mobility and comfort, the maximum breathing capacity increased, often by as much as 50 per cent, this increment being due to strengthening of respiratory muscles in an exercising patient as compared to his former status as a bed patient It was their opinion that compressing healthy lung tissue reduced breathing reserve but that this was compensated for by an increase in respiratory muscle power on return to health and exercise

In a series of segmental resections, Kelley and Pecora[10] reported definite improvement in ventilatory function (maximum breathing capacity) postoperatively when two, three, or four segments were resected, with a drop below the preoperative level when more than four segments were removed Our study does not support this finding To assume that the improved function is a direct result of segmental resection ignores pertinent factors such as improvement in respiratory status with rehabilitation exercise experience gained by repetition of a laboratory test and improved patient morale Overholt and associates[11] performed pulmonary function tests postoperatively in patients undergoing [illegible] A correlation was noted in that the [illegible] would approach the predicted normal level in [illegible] segments conserved with minimum post[illegible]

[illegible] six rib thoracoplasty, oxygen consumption [illegible] lung were diminished 10.6 per cent and 9.2 [illegible]. Total vital capacity was reduced 25.4 per cent, maximum [illegible] 11 per cent. A significant reduction in total vital [illegible] breathing capacity occurred in the majority of cases. [illegible] vital capacity for the operated lung occurred in [illegible] considerable in extent. Walking ventilation showed [illegible] after surgery, extremes being −3.9 L. and +5.2 L. [illegible] thoracoplasty in preservation [illegible] illustrated in Tables IV and V. Total vital capacity [illegible] segmental and lobe resection (Table IV) is [illegible] 11.1 per cent and 8.2 per cent respectively; maximum breathing [illegible] 11 [illegible] per cent and 19 per cent respectively. Table V [illegible] though not as pronounced as [illegible] thoracoplasty. Analysis of Tables II and III reveals no [illegible] number of lobes or segments removed and the [illegible] function loss.

SUMMARY

[illegible] conducted comparing the groups: five and six [illegible] lobe resection. Pulmonary [illegible] included bronchospirometry [illegible] capacity, maximum breathing [illegible] total lung func[illegible] [illegible] loss the most [illegible] group. A limited [illegible]

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COMPARISON OF THORACOPLASTY AND RESECTION THERAPY IN PULMONARY TUBERCULOSIS

PHILIP [illegible], M.D.

[illegible] M.D.

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MATERIAL AND METHODS

This study included 474 major procedures done by the combined surgical services of the Charity Hospital from Jan. 1, 1942, through Dec. 31, 1951. There were 321 staged extrapleural thoracoplasties, eighty-one lobectomies (including five segmental resections), and seventy-two pneumonectomies. Forty-three (53 per cent) of the lobectomies and thirty-six (50 per cent) of the pneumonectomies had concomitant thoracoplasties which were not included in the thoracoplasty group. Sixty-four (79 per cent) of the lobectomies were done on the upper lobes and seven (9 per cent) were done on the lower lobes. Ten (12 per cent) were right middle lobe lobectomies combined with upper or lower lobe excisions.

There were 244 male patients and 230 female patients. Three hundred seven patients were white and 167 were nonwhite. The highest incidence of operative cases was in the third to the fifth decades. A few resections were applied in the first decade of life, the youngest patient being 3 years old. Two thoracoplasties were done in patients over 60 years of age, the oldest being 66 years.

The majority of the cases had collapse therapy prior to major surgery. Two hundred and sixty-seven had pneumothorax, sixty had pneumoperitoneum, and twenty-three had both. The average duration of symptoms before thoracoplasty and before resection was the same—about two years.

Most of the surgical procedures were applied to extensive tuberculosis. Sixty-four per cent of the total series had far advanced disease* and 35 per cent had moderately advanced disease. Only five patients (1 per cent) had minimal disease. Sixty per cent of the cases were bilateral and 86 per cent were cavitary.

It should be pointed out that the long-range follow-up of our series could not be fully accomplished. Three hundred twenty patients were studied by roentgenograms and enough sputum studies to satisfy the N. T. A. classification of "active," "inactive," or "arrested." One hundred nineteen patients (27 per cent) had to be classified in a "probably arrested" group, because of limited sputum cultures or inability to obtain return visit of the patient. However, 67 per cent of the probably arrested group had been followed by roentgenograms and partial sputum studies by their clinicians for one to ten years and were considered by them to be arrested or inactive. The remainder of these cases were primarily patients done in the early years of this series who had been inactive or arrested at the last clinic visit and who could not be traced at the time of this study. The limitations of follow up were equally distributed among the various procedures being studied and did not seem to alter significantly their comparison (Table I).

RESULTS OF SURGICAL THERAPY

Thirty-five patients died immediately after surgery, a case fatality rate of 7.4 per cent. There were 103 additional failures (21.8 per cent) and 336

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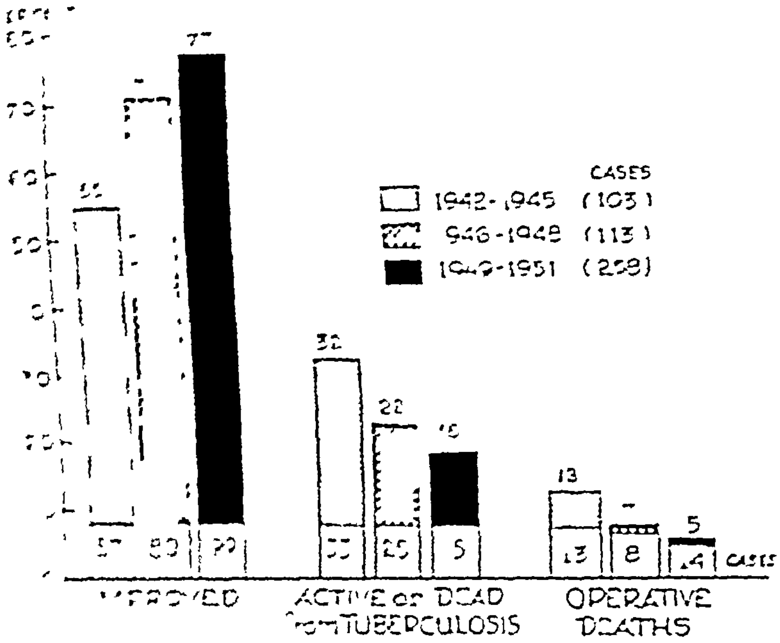
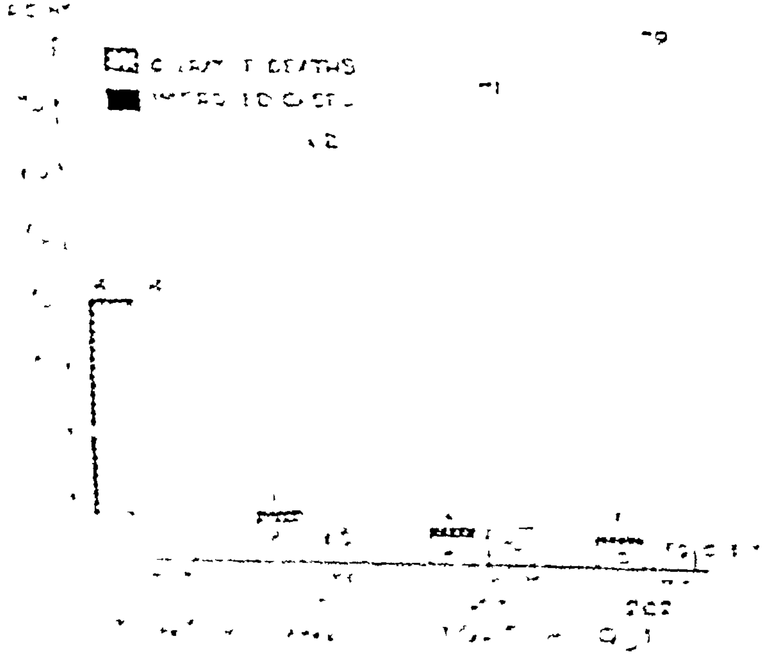
*The National Tuberculosis Association Classification of 1950 is used throughout this report.


CASES
1942-1945 (103)
1946-1948 (113)
1949-1951 (258)
70
60
50
55
77
32
22
13
5
13
8
14
5
CASES
IMPROVED
ACTIVE or DEAD from TUBERCULOSIS
OPERATIVE DEATHS


DEATHS

improved cases (70.8 per cent) postoperatively. The failures included all immediate postoperative deaths, all late deaths from tuberculosis and all living patients in which the tuberculosis remained active. The improved cases included all those classified as "inactive," "arrested," or "probably arrested" (Table I).

TABLE I. RESULTS IN 474 SURGICAL PROCEDURES

	THORACOPLASTIES		LOBECTOMIES		PNEUMONECTOMIES		TOTALS	
Improved cases	224		64		48		336	
Inactive		43		3		5		51
Arrested		110		35		21		166
Probably arrested		71		26		22		119
Unimproved cases	97		17		24		138	
Continued activity		43		6		10		59
Delayed deaths		30		8		6		44
Operative deaths		24		3		8		35
Total cases	321		81		72		474	

The entire series showed a steady improvement in results with the passage of time (Fig. 1). The total improved cases, that is, the salvage rate, rose from 55 per cent in the period 1942 to 1945 to 77 per cent in the period 1949 to 1951. The operative case fatality rate fell from 13 per cent to 5 per cent.

Improvement was most marked in the nonwhite patients, particularly since 1947 (Fig. 2). Before 1947, the nonwhite operative mortality rate was 40 per cent and the salvage rate was 40 per cent. Since then the mortality rate has fallen to 6 per cent and the salvage rate has risen to 71 per cent. With improved results, the application of surgery to nonwhite patients has increased (Fig. 3).

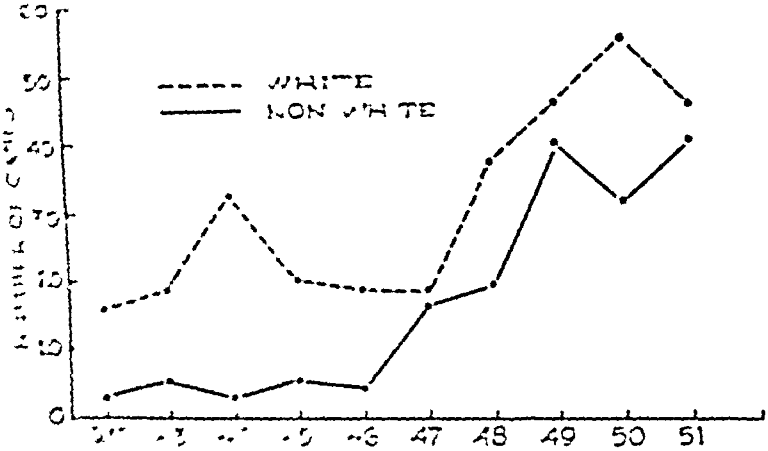
In the last five years, a marked increase in the annual number of operations has occurred. Before 1947, twenty to thirty cases were done per year. Since 1947, the number has increased steadily to the present annual rate of eighty or more (Fig. 4).

Until recently, staged extrapleural thoracoplasty of the selective (Alexander) type has been the treatment of preference when a major surgical procedure was indicated. Resections were performed only when thoracoplasty had failed or could not be reasonably expected to succeed. Since 1947, the number of resections has rapidly increased and, in the past two years, more resections than thoracoplasties have been performed (Fig. 4). It is apparent that resection is now frequently elected in patients who are suitable candidates for thoracoplasty. Elective resections in the total series comprise 82 per cent of the lobectomies and 38 per cent of the pneumonectomies (Table II). In the last two years twenty of the extrapleural thoracoplasties were of the one-stage Paulino type which has been described elsewhere.[10]

FACTORS INFLUENCING SURGICAL RESULTS

To determine the factors which might have specifically affected the mortality and salvage rates, the series was studied with regard to race, sex, age, use of streptomycin, extent of disease, period of time, and type of operative risk.

[illegible] The factors which significantly influenced the [illegible] operative risk of the patient and the [illegible] procedure [illegible]



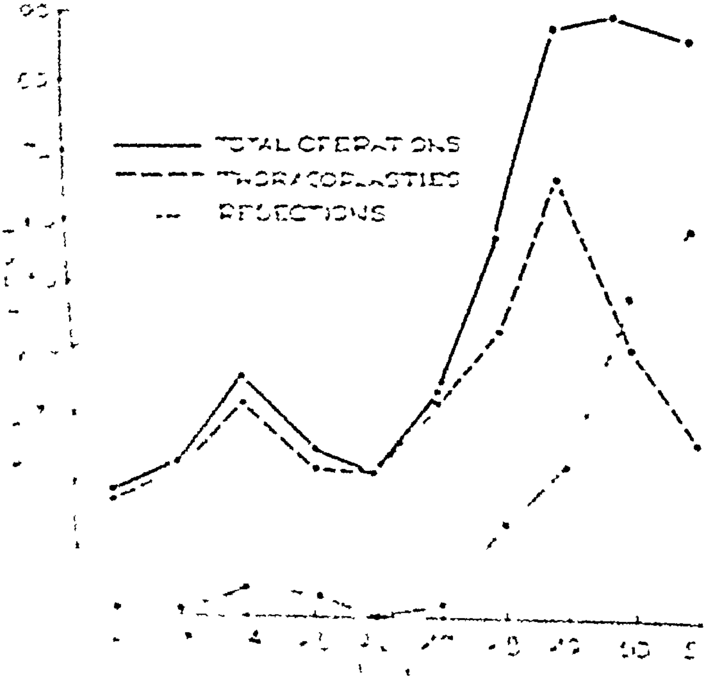


TABLE II INDICATIONS FOR RESECTION THERAPY

INDICATIONS	LOBECTOMIES		PNEUMONECTOMIES	
	CASES	PER CENT	CASES	PER CENT
Elective resection	66	81.5	27	37.5
Destroyed lung	–	–	18	25.0
Thoracoplasty failure	5	6.2	10	13.9
Empyema	–	–	8	11.0
Possible neoplasm	3	3.7	2	2.8
Endobronchial stenosis	1	1.2	2	2.8
Bronchiectasis	1	1.2	2	2.8
Tension cavities	2	2.5	1	1.4
Lower lobe disease	3	3.7	–	–
Resection failure	–	–	2	2.8
Totals	81	100.0	72	100.0

Operative Risk.—Determination of the operative risk of the patients included an evaluation of their over-all medical status as well as the extent of their tuberculosis. All the cases, regardless of the procedure done, were divided into good, fair, and poor-risk groups and the mortality and salvage rates of the groups were compared. As expected, the good operative risks had the best surgical results (Fig. 5). These differences were also statistically significant, the probability of chance difference being about 1 per cent.

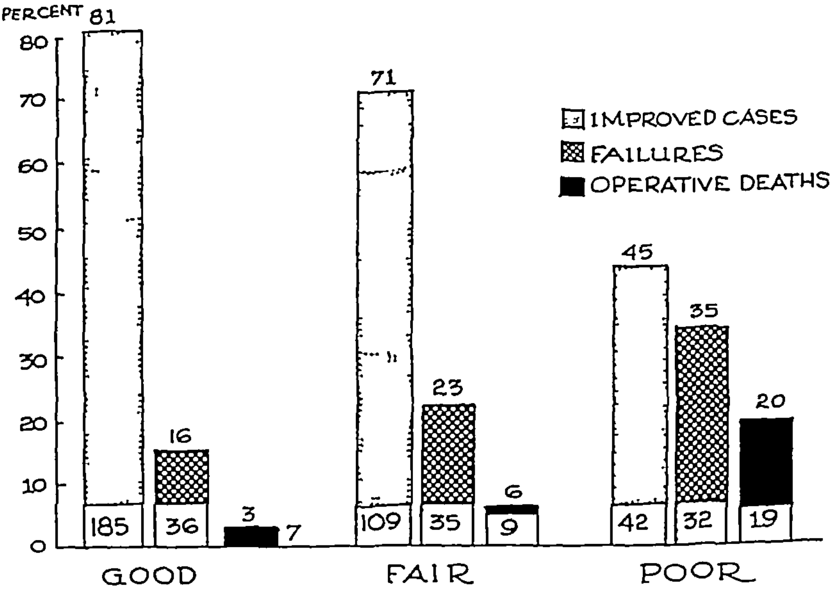
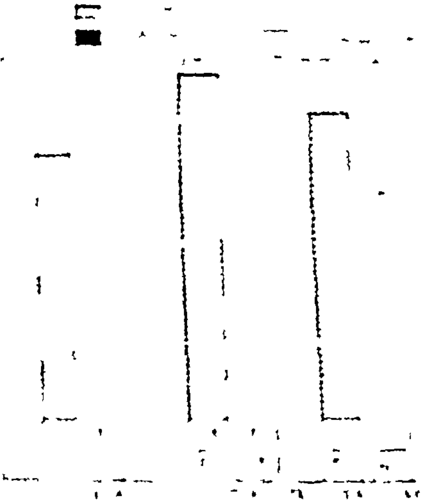
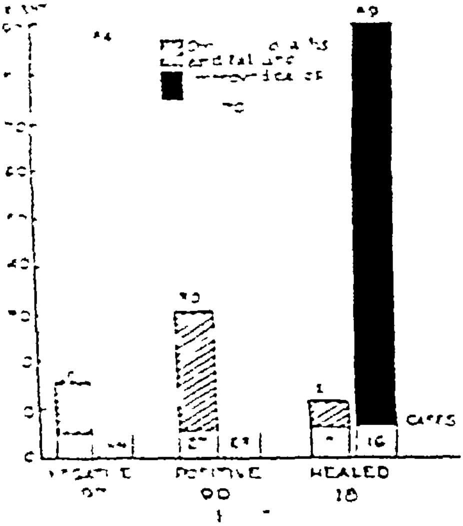


Fig. 5.—Comparison of surgical results by operative risk.

Period of Time.—Since 1947, the use of streptomycin, adequate transfusions, establishment of postoperative recovery rooms, creation of a separate thoracic service, and better selection of patients have acted to safeguard the tuberculous patient undergoing major thoracic surgery. Therefore, as previously noted, the best results were obtained during the latter years of the series (Fig. 1). These time differences were statistically significant, the probability of chance being 2 per cent.




49
30
CASES
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POSITIVE
90
HEALED
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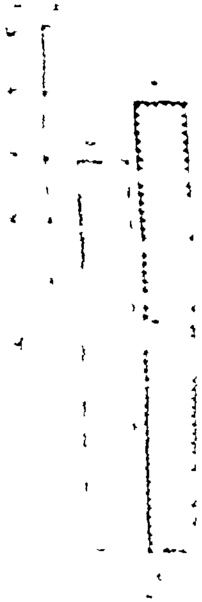
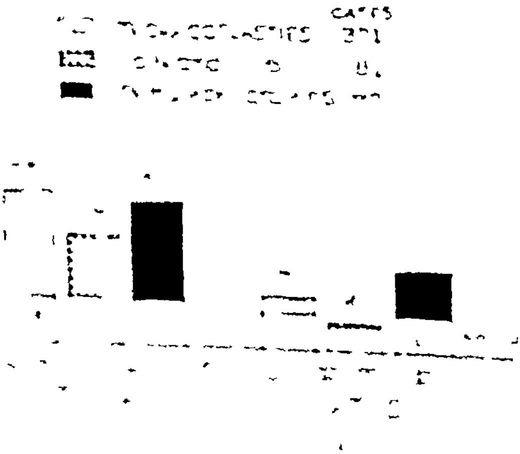



CASES

Three incidental findings of interest also were noted.

1. Whether the tuberculous process was unilateral or bilateral exerted a considerable influence on the salvage rates of the resections (Fig. 6). It did not, however, influence the final results in the thoracoplasties and did not significantly affect the operative case fatality rate of any of the procedures.

2. The N.T.A. classification of the extent of pulmonary disease was a fair index for predicting the surgical result. As would be expected, the far advanced cases had a lower salvage rate and a higher mortality rate than the moderately advanced or minimal cases.

3. The surgical result was closely correlated with the bronchoscopic findings just before surgery. Those cases with no endobronchial disease or with healed endobronchial disease did well. Those with active endobronchial disease did poorly (Fig. 7).

COMPARISON OF SURGICAL RESULTS BY PROCEDURE

The crude mortality and salvage rates of each of the procedures are shown in Fig. 8. The best results were obtained with the lobectomies, the poorest with the pneumonectomies. The salvage rate for lobectomy was 79 per cent as compared with 70 per cent for thoracoplasty and 67 per cent for pneumonectomy. The operative mortality rate for lobectomy was 4 per cent as compared with 7 per cent for thoracoplasty and 11 per cent for pneumonectomy. These differences, however, are not statistically significant, for the probability that they are due to chance is 22 per cent.

About one-half of the thoracoplasties were done before 1947 and did not have the benefit of streptomycin and improved patient management. The majority of the resections were done after 1947 and did have these advantages. In addition, the lobectomy series was heavily weighted with good risk patients having moderately advanced or minimal disease. The thoracoplasty and pneumonectomy series had a large number of poor risk patients with far advanced disease (Figs. 9 and 10).

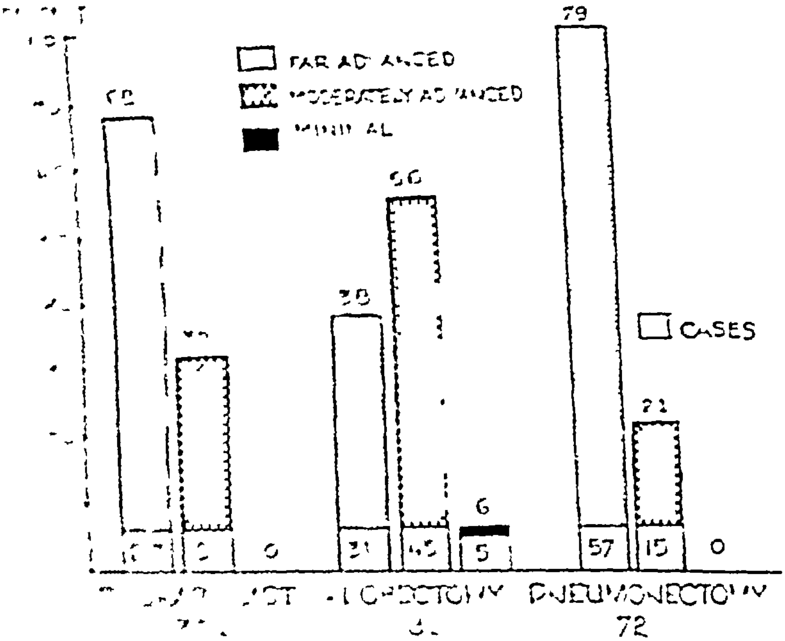
Adjustment of the crude results for these group differences had an equalizing influence. The differences in the adjusted mortality and salvage rates were even less than in the crude form (Fig. 11). On the basis of operative results no procedure was found to be superior to the others.

COMPLICATIONS

Three major types of complications occurred: (a) immediate postoperative deaths, (b) delayed postoperative deaths from tuberculosis, and (c) continued postoperative tuberculous activity.

As shown in Table III, the number of immediate postoperative deaths for thoracoplasties and resections was almost the same (7.5 per cent and 7.4 per cent, respectively). The most common causes of death in both procedures were pulmonary in type and comprised approximately three-fourths of the immediate deaths in the thoracoplasty series and one-half of the immediate deaths in the resection series. Cardiovascular and renal complications caused [illegible] The over-all case fatality rate in both [illegible] impossible to use this as a criterion for [illegible] the other.

[illegible] of the causes of delayed post[illegible] tuberculous activity. The [illegible] continued activity following either



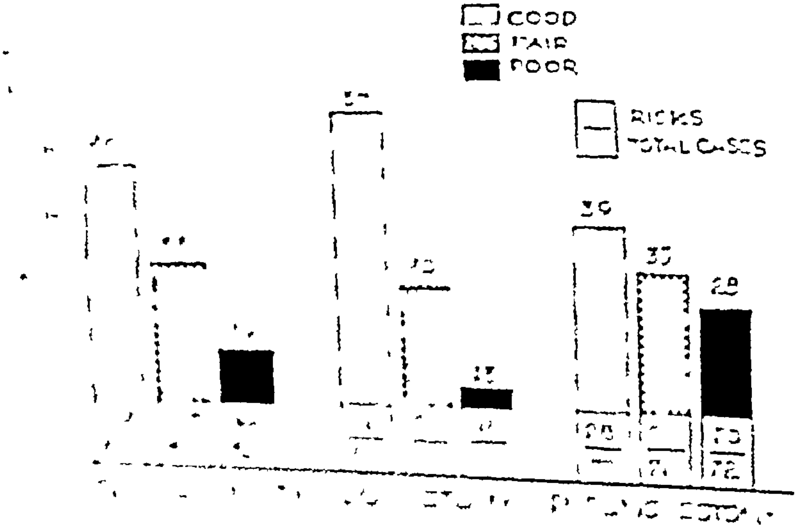


TABLE III CAUSES FOR IMMEDIATE POSTOPERATIVE DEATHS

CAUSES	THORACO-PLASTIES	PER CENT	LOBEC-TOMIES	PNEUMO-NECTOMIES	ALL RE-SECTIONS	PER CENT
Pulmonary						
Respiratory insufficiency	6	1.9	–	1	1	0.7
Atelectasis	5	1.7	–	1	1	0.7
Pulmonary embolism	3	0.9	–	2	2	1.3
Airway obstruction	1	0.3	1	–	1	0.7
Tuberculous pneumonia	3	0.9	–	–	–	–
Blown out bronchial stump	–	–	–	1	1	0.7
Bacterial pneumonia	1	0.3	–	–	–	–
Lower Nephron disease	2	0.6	–	–	–	–
Cardiovascular						
Congestive failure	1	0.3	–	2	2	1.3
Cardiac arrest	1	0.3	–	–	–	–
Shock	1	0.3	–	1	1	0.7
Hemorrhage	–	–	2	–	2	1.3
Totals	24	7.5	3	8	11	7.4

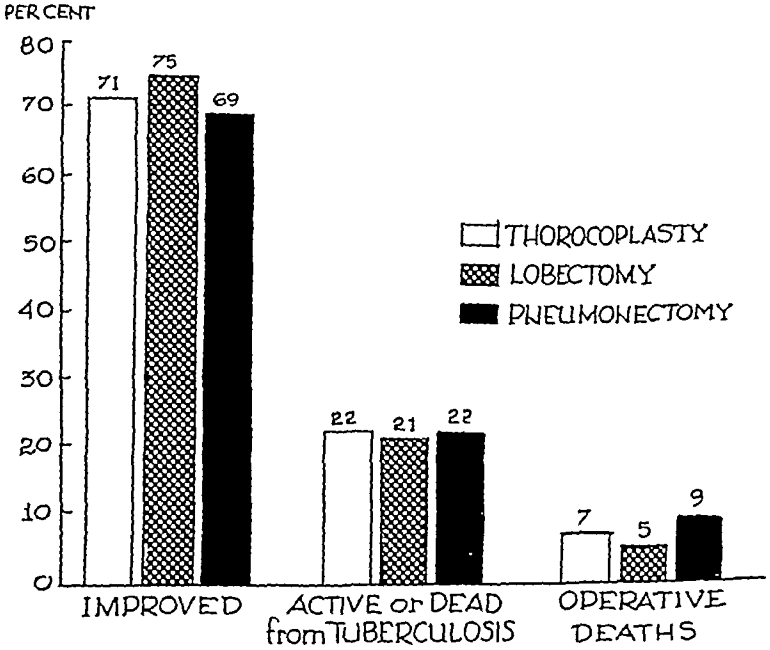


FIG. 11.—Comparison of mortality and salvage rates by surgical procedure after correction for *race, operative risk and period of time.*

thoracoplasties or resections was progression of the disease (Tables IV and V). The remaining causes varied with the type of procedure, but the over-all case incidence in all procedures was essentially the same.

SUMMARY

A statistical review of 474 cases of major surgical therapy in pulmonary tuberculosis done during the ten-year period 1942 to 1951 has been presented. This included 321 thoracoplasties, eighty-one lobectomies, and seventy-two pneumonectomies.

[illegible]

[illegible] 105

[illegible] were the race [illegible] treatment and the period of time [illegible] important [illegible] improved patient management

[illegible] resection [illegible] The [illegible] classification [illegible] surgical results [illegible] findings [illegible]

[illegible]

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DIVERTICULA OF THE ESOPHAGUS

[illegible] Cases

[illegible] M.D. [illegible] P. [illegible] M.D.

[illegible] M.D. [illegible]

[illegible] recognized as a clinic[al] entity since [illegible] more easily accessible [illegible]. There [illegible] surgically treated for many [illegible] surgery [illegible] is gained to per[illegible] surgical [illegible] [illegible] various surgical [illegible] esophagus. [illegible] treatment for these dis[illegible] [illegible] Hypopharyn[geal] [illegible]

[illegible] the esophagus may be classed

[illegible] cervical [illegible]

[illegible] diverticulum [illegible] the upper esopha[gus] [illegible] affecting the lower esophagus

[illegible] compose [illegible] per cent of

[illegible] are seen [illegible] presumed [illegible] pressure of the hard cartilage could produce degeneration of the aging muscle. Holmgren's observation of roentgenographically visible, inconstant diverticulum-like changes in the border zone between the pharynx and the esophagus is interesting. Holmgren expressed the opinion that these changes were referable to anatomic conditions in the affected zone and pressure changes in and around the pharynx occasioned by deglutition. These changes might, he thought, be precursors of diverticula of this junction despite the fact that no observations are recorded of such a preliminary stage in pharyngeal diverticula.

Even though the primary cause of extrathoracic esophageal diverticula is uncertain, it is known that the diverticula are progressively enlarged by repeated distention with swallowed food, so that in time the esophagus is obstructed and a vicious circle is established which can be broken only by extirpation of the defect.

Gross Pathology.—The pouch may vary in size from a few cubic centimeters to the size of a clenched fist. Its wall consists only of a mucous and a submucous layer. In the rare congenital cases however a muscular layer is also present.

Symptomatology.—The size and shape of the diverticulum are the determining factors in regard to symptoms. Broad based small diverticula produce only occasional and transitory symptoms when food particles of unsuitable consistency or size are retained. When the form becomes saclike with a true neck, food and swallowed air accumulate and symptoms, chiefly dysphagia and regurgitation appear. Sometimes a gurgling noise is audible in the sac which if large may be felt on palpation. Often the patient manages for some time to dislodge the contents of the sac by certain movements of the head and neck. But when the diverticulum becomes so large that it interferes with nutrition severe weight loss may result. A characteristic description of the condition is as follows: swallowing is fairly easy at the beginning of a meal but becomes progressively more difficult until maximum dilatation of the diverticulum prohibits further consumption and the esophageal contents are vomited.

Diagnosis.—Although the symptoms may suggest a diverticulum roentgenographic study is necessary to confirm the diagnosis. Esophagoscopy permits determination of the size and situation of the defect, but carries a risk of perforation.

Complications.—Mechanical and chemical irritation produced by distention of the sac and decomposition of the retained food give rise to a local esophagitis which in rare instances may result in perforation. Malignant degeneration may occur from chronic irritation.

The most important complications however are bronchopulmonary. A diverticulum which has filled during the day may, when the patient is asleep or otherwise in the supine posture or when the pharyngeal reflexes are weakened, spill its contents into the air passages and give rise to aspiration pneumonia, lung abscesses or bronchiectasis. The traumatic complications of esophagoscopy must also be listed as complications of esophageal diverticula.

[illegible]

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[illegible] diverticulum may be
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[illegible] removed in [illegible]
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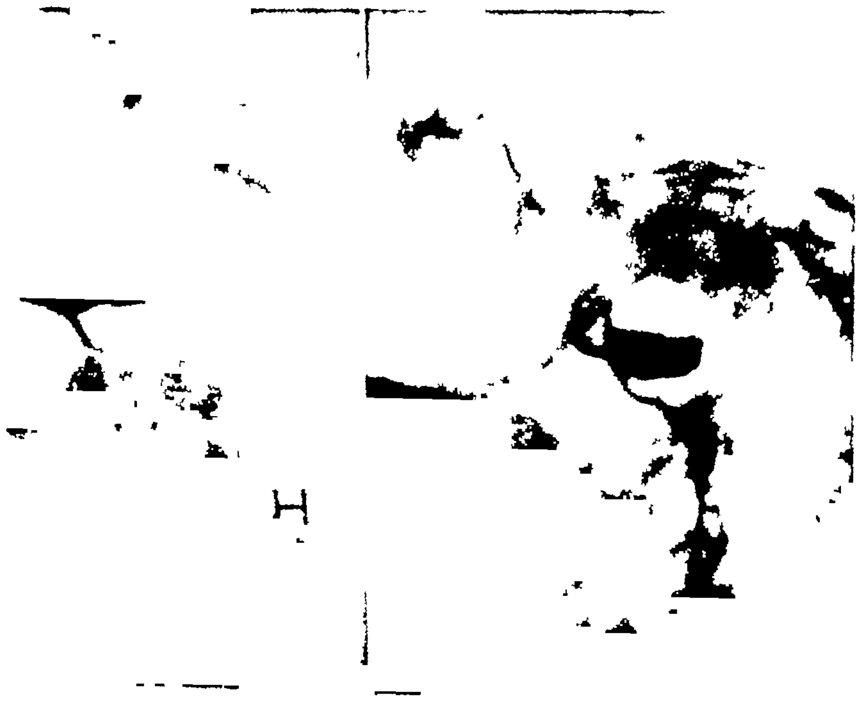
[illegible] and [illegible]
[illegible] is dissected
[illegible] esophageal
[illegible] is passed
[illegible]

TABLE I EXTRATHORACIC DIVERTICULA

NO	INITIALS	AGE AND SEX	SYMPTOMS	DURATION OF SYMPTOMS	PREOP COMPLICATIONS	DATE OF OPERATION	P O COMPLICATIONS	RECURRENCE	PRESENT STATUS
1	G W	49 M	Dysphagia regurgitation	4 yr	–	2/ 9/34	Suture insufficiency, fistula	+	Symptom free
2	O G	39 M	Dysphagia	1 yr	–	9/27/34	–		Unknown
3	T P	75 F	Dysphagia	1½ yr	–	9/16/36	–	+	Symptom free
4	F P	79 F	Dysphagia	10 yr	–	2/27/47	–		Symptom free
5	G K	67 M	Dysphagia	20 yr	–	1/14/48	–	–	Symptom free
6	I I	69 M	Dysphagia	11 yr	–	2/11/49	Paralysis of recurrent laryngeal nerve	–	Symptom free
7	J S	74 M	Dysphagia, regurgitation	5 yr	–	6/17/49	–	+	Symptom free
8	A H	71 M	Dysphagia	8 yr	–	7/ 7/49	–	+	Symptom free
9	I K	33 F	Dysphagia	¼ yr	–	1/25/50	–	–	Symptom free
10	G A	70 M	Dysphagia	20 yr	–	8/ 8/50	–	–	Symptom free

[illegible] kilograms [illegible] was confirmed by [illegible] history of [illegible] complications [illegible] very long [illegible] diverticulum [illegible] to particularly [illegible]

[illegible] retention in [illegible] parenteral [illegible] Anti[illegible]



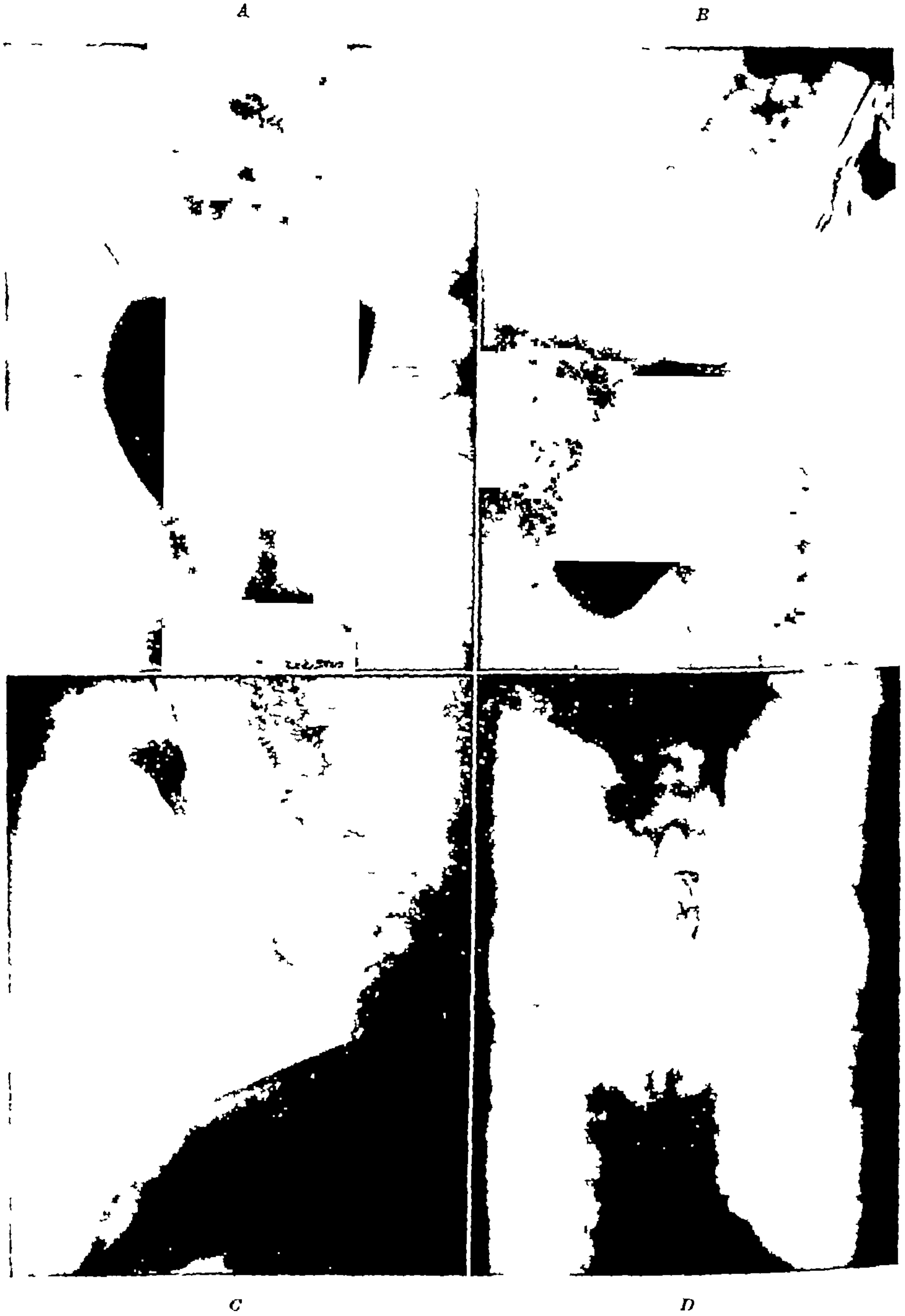


Fig. 2.—(Case 10.) A and B, Preoperative barium study. C and D, Postoperative barium study.

[illegible] In addition [illegible] [illegible] or follow up [illegible] [illegible] died [illegible] and the other [illegible] and [illegible] The second [illegible] in loam [illegible] 40 [illegible] However all eight [illegible]

[illegible] The [illegible] fairly long [illegible]

[illegible] conditions for [illegible] employed [illegible] series [illegible]

Whatever the actual causal mechanism a pulsation factor to the development of the diverticulum is added by swallowed food A congenital defect in which secondary infection produces adhesion to adjacent structures cannot of course be excluded Contrasted against congenital causes there is the fact that symptoms generally do not appear until fairly late in life but it is known that esophageal diverticula may be silent for many years Each theory contains no doubt, some truth and it is probable that several etiological factors operate together Pathologic and histologic study do not elucidate the question

Gross Pathology—Most epibronchial diverticula are small and cone shaped with the base opening into the esophagus As a rule all coats of the esophagus are found in the pouch which may be free from inflammatory changes but which is usually firmly adherent to the adjacent tissues In some cases there is fistulation to the lungs or bronchi

Symptomatology—These diverticula may be incidental findings in a search for another disease Symptoms directly referable to an esophageal anomaly are fairly unusual but they may be manifested as dysphagia or a feeling of tension or pain in the chest The severity of the symptoms varies with the filling and emptying of the esophagus and with the presence or absence of infection The symptoms of infection may quite overshadow those of the diverticulum as such Since the history gives little help in establishing the diagnosis barium study and/or esophagoscopy must be undertaken

Complications—Patients who seek medical advice for this condition generally do so when complications have occurred Infection the commonest complication may gradually produce perforation of the diverticulum with fistulation to adjacent organs Bronchiectasis and lung abscesses which appear to be primary conditions may have their origin in perforation of such an esophageal diverticulum Malignant degeneration of the diverticular mucosa is a possibility not to be ignored

Treatment—When a fistula has formed surgical intervention is clearly indicated It is not clear whether or not silent diverticulum which is discovered accidentally should be excised The consensus of opinion in the literature seems to be that regular roentgenographic observation is adequate If symptoms have appeared excision is advocated if there is fistulation to the lung lobectomy or segmental resection to eradicate the infection should be performed Diverticulopexy and invagination of the sac were previously employed but have now fallen into disuse

The principles outlined for the preoperative treatment of extrathoracic diverticula apply also to the epibronchial variety

Excision of uncomplicated diverticula is carried out through a thoracotomy incision which is closed without drainage When lung tissue is resected underwater suction drainage is generally employed

The postoperative management of such patients therefore is not notably different from that following pulmonary surgery for other conditions Fluids are given as stated previously [illegible] portion [illegible] although [illegible] and Barnes [illegible] in the [illegible]

[illegible] All [illegible] layer [illegible]

[illegible] Frequently the [illegible] though [illegible]

TABLE II INTRATHORACIC DIVERTICULA

NO	INITIALS	AGE AND SEX	SYMPTOMS	DURATION OF SYMPTOMS	PREOP COMPLICATIONS	DATE OF OPERATION	P O COMPLICATIONS	RECURRENCE	PRESENT STATUS
1	E J	30 F	Recurrent pneumonia	4 yr	Bronchiectasis	3/ 6/45	–	–	Symptom free
2	K I	41 F	Lung abscess	9 yr	Lung abscess	5/21/47	–	–	Symptom free
3	A E	53 M	Dysphagia	½ yr	–	4/23/48	–	–	Symptom free
4	M J	55 F	Recurrent pneumonia	12 yr	Esophagobronchial fistula	5/16/49	–	–	Symptom free
5	R S	60 M	Regurgitation	20 yr	–	2/ 1/51	–	–	Unimproved
6	A L	61 F	Recurrent pneumonia	7 yr	Esophagobronchial fistula	2/ 7/52	–	–	Symptom free
7	F J	50 F	Dysphagia	5 yr	–	4/18/52	–	–	Symptom free

[illegible] the condition The last-
[illegible] and Parnes for multiple
[illegible] atresia or cardiospasm
[illegible] and postoperative management of
[illegible] said concerning epibronchial

[illegible] diverticula in operations for cor-
[illegible] indicate an infrequent association

[illegible]

[illegible] on the epibronchial
[illegible] The cases are listed in Table II
[illegible] years of age the majority
[illegible] cases the dominant symptom was
[illegible] retrosternal point A history
[illegible] in the others In two pa-
[illegible] previously been incised and
[illegible] recurred due to infection
[illegible] the patients came to opera-
[illegible] fistula The association with
[illegible] when the chest was
[illegible] diagnosis was bronchi-
[illegible] esophagobronchial fistula
[illegible] operation
[illegible] esophagobronchial
[illegible] in the patients Such
[illegible] bronchopulmonary dis-
[illegible] obtained the diag-

[illegible]
[illegible] symptom
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[illegible]

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[illegible] CYSTIC THYMOMA

[illegible]

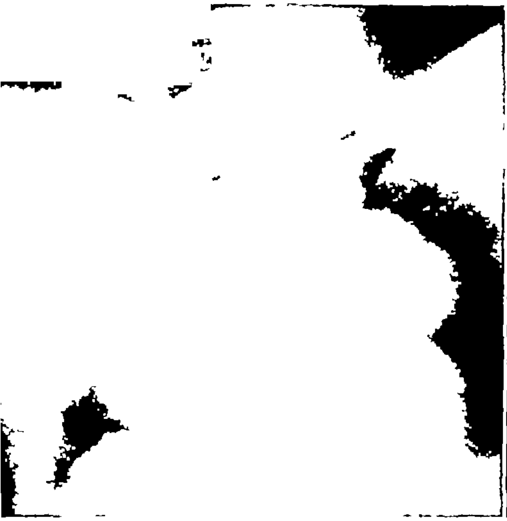


Fig. 1

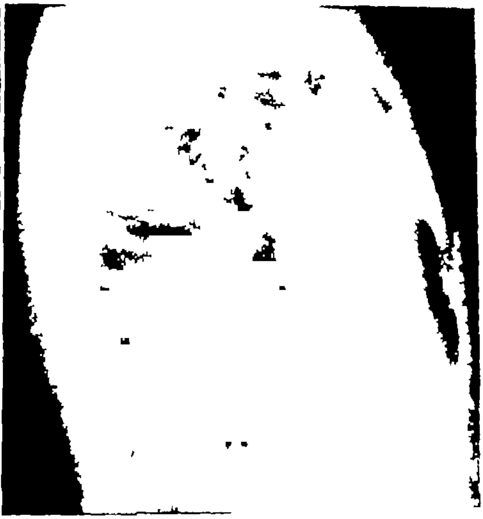


Fig. 2

Fig. 1.—Planographic study shows the large thoracic shadow mostly in the right chest, but with an extension to the left.

Fig. 2.—Lateral chest film shows the mass to be anteriorly placed. The esophagus was not displaced as evidenced by normal position on barium swallow examination.

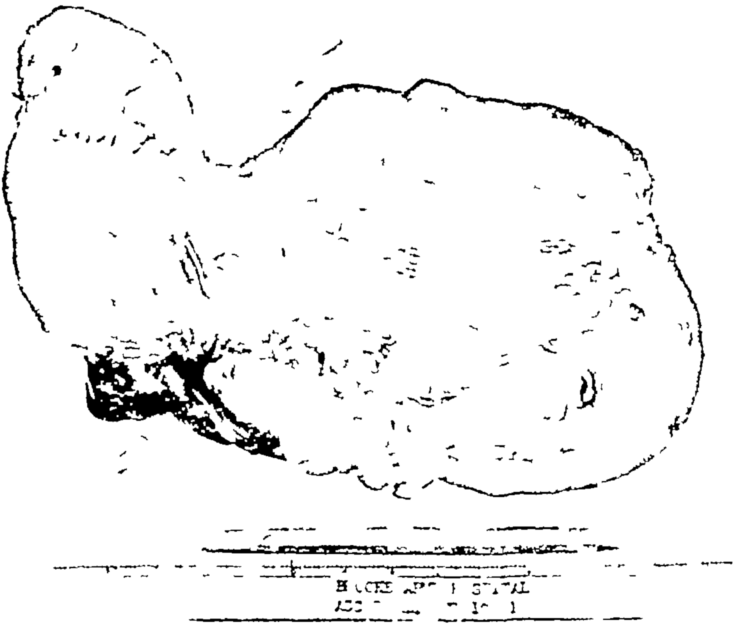
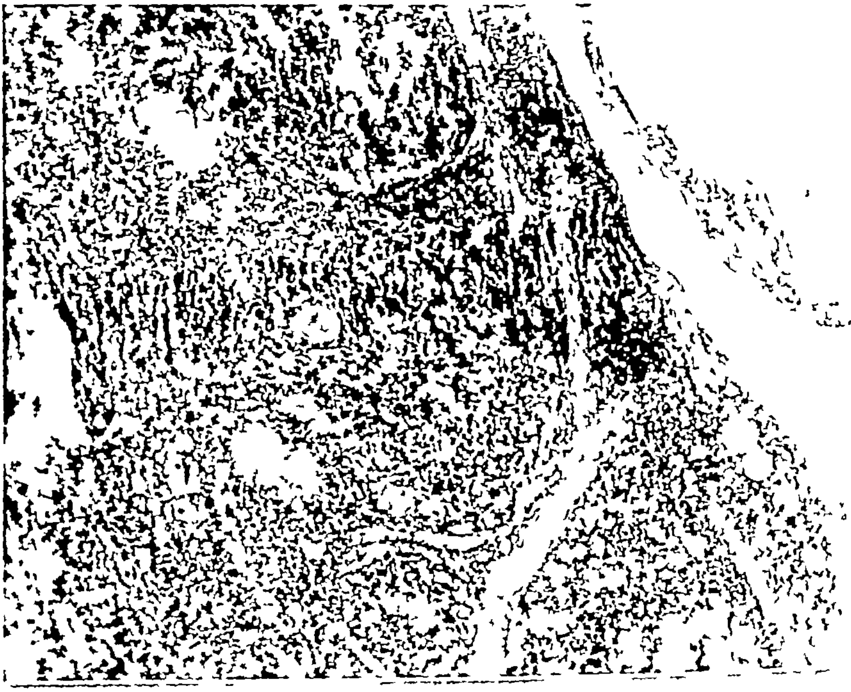


Fig. 3.—The gross specimen measured 18 by 9.4 by 6.4 cm. and was a thin walled cyst with several masses of solid tissue in its wall.

In reviewing the literature we find only one other benign thymic tumor or epithelial anlage origin which is similar to the one described Blalock and coworkers[12] reported a smaller benign cystic thymoma in a patient with myasthenia gravis Although there was no microscopic evidence of thymic tissue in their case, it was assumed from the position of the mass and from the clinical relationship to myasthenia gravis that the tumor represented a necrotic thymic

Fig 4



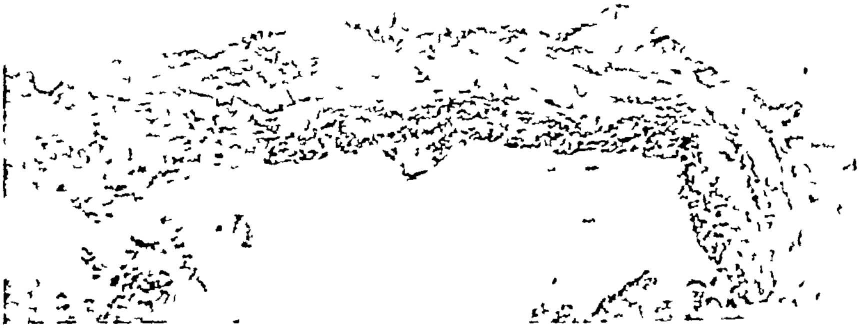


Fig 5

Fig 4 —The solid tissue in the cyst wall showed typical thymic tissue containing Ha ll s corpuscles

Fig 5 —The cyst wall was very thin with lymphoid tissue in its wall surrounded by areolar tissue

PRIMARY LYMPHOSARCOMA OF THE LUNG

A Report of Two Cases

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H. BRODIE STEPHENS, M.D.
SAN FRANCISCO, CALIF.

VERY few reports of primary lymphosarcoma in which the lung was the site of origin have appeared in the literature. In two large series of malignant lymphomas reviewed about a decade ago,[1, 2] only one case (from a total of 814) was considered to have arisen from the pulmonary parenchyma. Since that time seven other cases have been recorded.[3-9] (Beck and Reganis supplement their case report with data concerning eight additional cases treated but not reported by other surgeons.)

At the University of California Hospital, two patients with primary lymphosarcoma of the lung have been operated upon in the past twenty-two years. A discussion of these two cases is presented for analysis of their diagnostic and therapeutic characteristics.

CASE REPORTS

CASE 1.—M. K., a 68-year-old housewife, entered the University of California Hospital for the first time in March, 1951, complaining chiefly of a cough which had been present for eight months and of hemoptysis of three months' duration. The patient had some exertional dyspnea associated with these symptoms and had lost eight pounds. No pleuritic pain, chills, fever, or night sweats had occurred. The patient denied the use of nose drops with oil bases or the inhalation of foreign material. The past history, family history, and system review were noncontributory.

Positive findings on physical examination were confined to the thorax. Diminished vocal fremitus and dullness were present on the left side. Breath sounds were of increased volume and pitch, and crepitant and subcrepitant râles were audible over the posterior inferior left lung field.

Routine laboratory work showed a normal blood and differential leukocyte count. Urinalysis was normal, and the Kahn and Kolmer tests were negative. X-ray films of the chest (Fig. 1) revealed consolidation of the left lower lung field. On the lateral projection the mass seemed to be limited to the left lower lobe.

Bronchoscopic examination demonstrated that the tracheal carina was displaced to the left. An area of neoplastic tissue was observed in the proximal portion of the left lower lobe bronchus. Histologic study of a biopsy specimen obtained from this area showed only fragments of connective tissue infiltrated with lymphocytes.

At operation the left lower lobe was found to be smaller than normal and it did not expand on inspiration. A solid mass of neoplastic tissue completely filled the area from the hilus to the periphery. The process also infiltrated the hilar area of the left upper lobe; the entire upper lobe showed diffuse involvement although not as dense as that in the lower lobe. A left pneumonectomy was performed. None of the mediastinal nodes were grossly involved.

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When examined in the pathologic laboratory the specimen consisted of a firm grayish white lobulated mass with indefinite margins On cut section the surface was pearly gray glistening and presented a solid infiltrating picture The pleura was intact

Microscopic sections (Fig 2) showed a solid mass of lymphoid cells which completely replaced the lung parenchyma The cells were larger than mature lymphocytes with minimal cytoplasm, vacuolated nuclei, and well-defined nucleoli Mitotic figures were frequent There was almost no stroma and the bronchial cartilages were eroded by the tumor The diagnosis of lymphosarcoma with primary origin in the pulmonary parenchyma was made

Postoperatively the patient received x ray therapy in the amount of 2000 r to the left mediastinal area anteriorly and posteriorly and was discharged in good condition

She was last seen two years postoperatively Physical and chest x ray examinations at that time demonstrated no evidence of recurrence

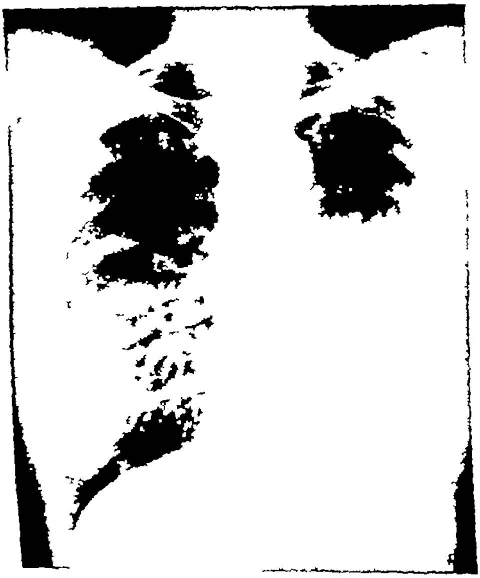

Fig 1—Note the ill-defined hazy density in the left lower lung field

Case 2—E R., a 45-year-old woman entered the University of California Hospital for the first time in May 1948 for investigation of an asymptomatic mass in the left chest which had been demonstrated by a routine chest x ray examination one and one half months before entry

After discovery of the mass the patient became aware of intermittent aching pain in the left chest which radiated to the interscapular region Three isolated episodes of blood streaked sputum had occurred one and one half years previously without other associated cardiorespiratory complaints There had been no recognized weight loss

Physical examination was entirely negative as were the laboratory studies including cytologic examination of sputum The tracheobronchial tree was normal throughout by bronchoscopic examination The roentgen ray films of the chest (Fig 3) demonstrated a mass in the left hilar region with streaks of dense tissue extending toward the periphery There was a small area of calcification overlying or within the mass

On the basis of these findings a left pneumonectomy was performed A firm tumor mass 6 0 cm in diameter was found arising from the anteromesial portion of the left upper lobe The tumor had penetrated the visceral pleura, and numerous enlarged hilar

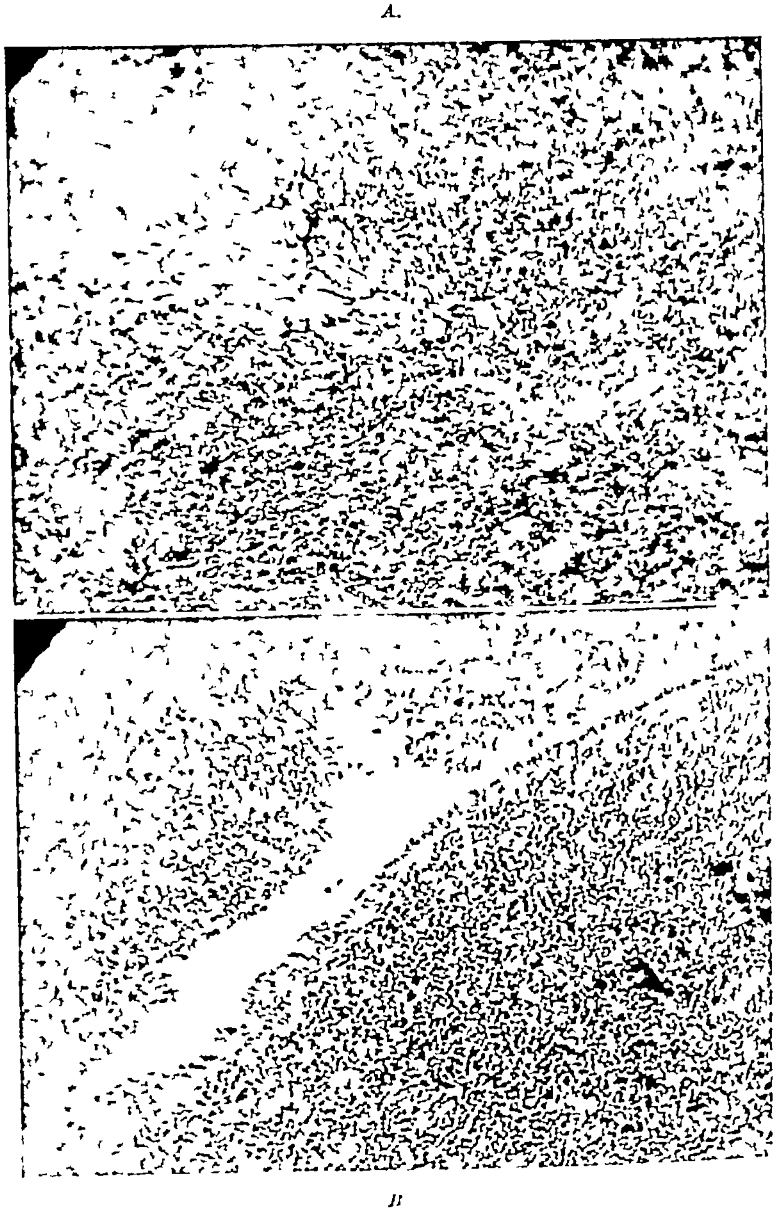

Fig. 2.—A, The lung parenchyma is almost totally replaced by tumor tissue. B, A generous capillary network is seen throughout the section. Note the massive infiltration by the lymphocytic cells.

nodes overlay the pulmonary artery The mass was firmly adherent to the hilar structures, and there were dense vascular adhesions between the tumor and the aorta

The pathologic report indicated that the tumor extended to the anterior surface of the lung Its site of origin lay approximately 1.0 cm. distal to the region of the take off of the upper lobe bronchus from the main stem bronchus on the left The bronchi had smooth, pinkish gray mucosa and were not grossly involved The hilar nodes were soft, edematous, anthracotic and contained no metastases

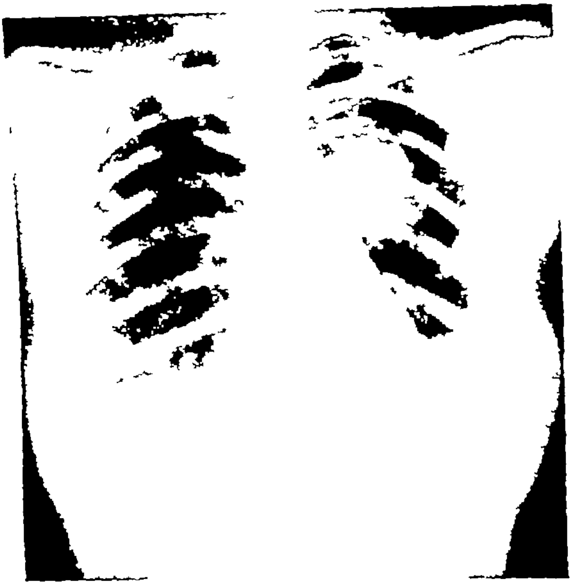

Fig 3 —Note the well defined mass in the left hilar region The peripheral streaking was a prominent feature on the x-ray film.

Microscopic sections (Fig 4) showed that the tumor was composed of a solid sheet of fairly uniform cells, which varied only slightly in size The cells had large oval nuclei with delicate chromatin and one to two nucleoli Mitoses were rare The cytoplasm was scanty and small capillaries ran through the tumor In some areas, large amounts of hyaline collagenous connective tissue were present It is significant that none of the hilar lymph nodes were involved by the malignant process. The pathologic diagnosis was primary lymphosarcoma of the lung

The patient's postoperative course was uneventful. She received no radiation therapy When last seen five years postoperatively, there was no demonstrable evidence of recurrence, either by physical or chest x ray examination

DISCUSSION

Of the two patients observed at the University of California Hospital both had symptoms referable to the respiratory system In one case as in four of the cases previously reported, the patient sought medical consultation which led to diagnosis of the complaint In the other case, as in three of those previously reported, the lesion was first demonstrated by a routine chest survey film Both of our patients were women, as have been a preponderant number of those previously reported Our patients were 68 and 45 years of age respectively The age range in the cases previously reported was 34 to 68 years, with an average age of 46 years

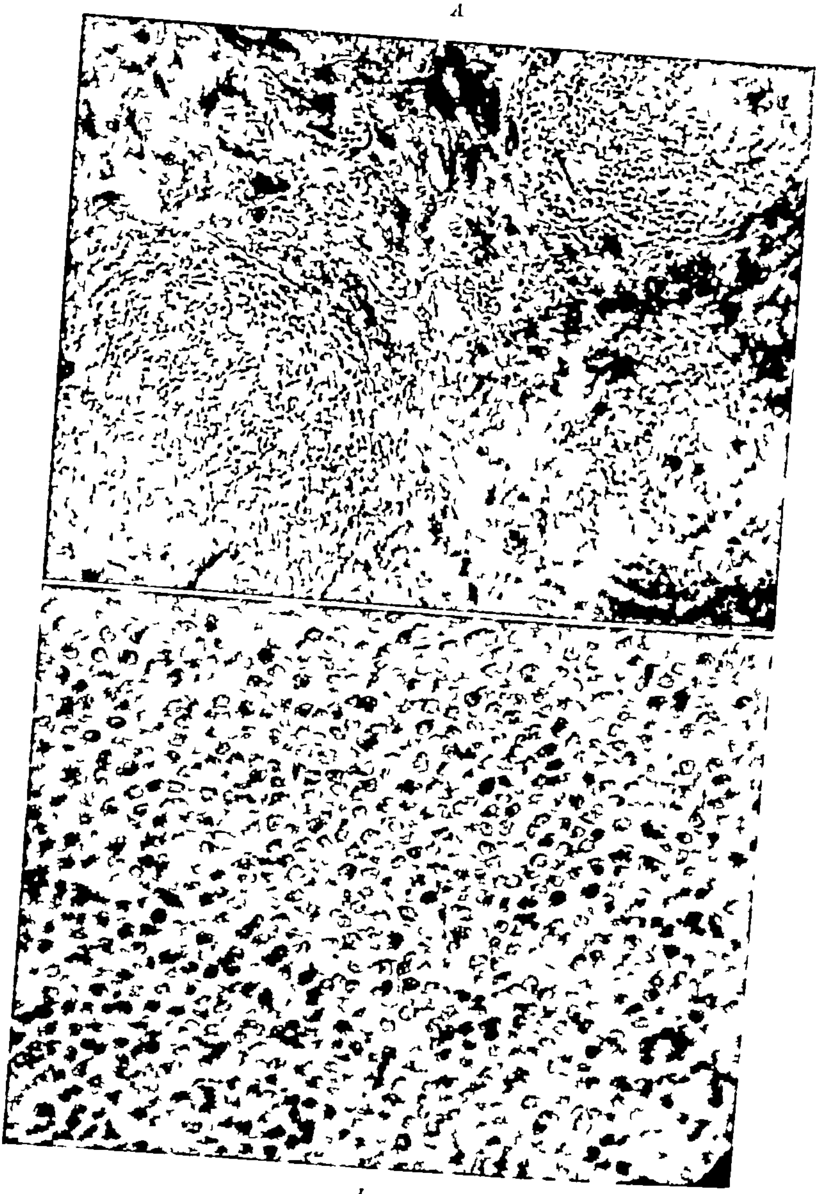

Fig. 4.—A, Large amounts of hyaline connective tissue arranged in strands can be seen between islands of tumor tissue. B, The uniform appearance of the cells is evident.

As would be expected, cytologic studies were negative in both of our cases This is probably due to the fact that lymphosarcomas do not tend to exfoliate cells as do bronchiogenic carcinomas Even when lymphosarcoma is suspected, however, cytologic examination should be performed, since the diagnosis is only presumptive until the tumor is examined at operation and in the pathologic laboratory

It is our opinion that wide excision by pneumonectomy accompanied by mediastinal lymph node dissection is the treatment of choice for primary lymphosarcoma of the lung The use of postoperative irradiation therapy to the mediastinal lymph node-bearing area must be considered since lesions of this type respond favorably to x-ray therapy

The prognosis appears to be significantly more favorable in patients with primary lymphosarcoma of the lung than in patients having bronchiogenic carcinoma

SUMMARY

The case histories of two patients with primary lymphosarcoma of the lung are presented Although the period of follow-up is not yet sufficient for incontrovertible evaluation, it appears that primary lymphosarcoma of the lung can be treated effectively by either extensive surgery alone or in combination with postoperative x-ray therapy

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ACQUIRED NONMALIGNANT ESOPHAGOTRACHEOBRONCHIAL FISTULA

Report of Two Cases

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THE causation and pathology of nonmalignant fistula formation between the esophagus and tracheobronchial tree has been well discussed previously by several authors[1-3] Coleman and Bunch,[3, 4] in 1950, reported seventy-five cases from the literature and their own experience Since that time, seven additional cases have been reported The location of these lesions together with our two, and the forty-four in Coleman and Bunch's series in which location was known, is shown in Fig 1 a total of fifty-three lesions

Tables I and II (after Coleman and Bunch) show the etiology of the whole presently reported series of eighty-four cases Of particular interest were the reports of Maier,[6] who felt that broncholiths might possibly be causative in his two cases, and Paviot and Demuleau,[10] who reported a case of fistula secondary to extrapleural Lucite ball plombage Two cases were reported in a discussion by Abbott,[11] which are not included in this series because of minimal data

Table III brings up to date the surgical management of this condition Of the nine new patients, one was cured by cauterization and one (following a lye burn) by exclusion of the damaged esophagus and fistula Three patients were cured by pulmonary resection and closure of the esophagus Division of the fistula with closure of both trachea and esophagus was performed in four cases, with two deaths, including one of the authors' cases

Case 1 —L T (VAMTG, 82 878) was a 30 year old white man who had been in an automobile accident on March 24, 1953 He was unconscious for two hours, was taken to another hospital, and then transferred on the following day Vital signs were normal on admission The neurological examination was negative There were numerous abrasions and lacerations Anteriorly at the base of the neck, there was ecchymosis, swelling, and subcutaneous emphysema The hypopharynx was bluish, as if discolored by blood, although no bulging was present There was some edema of the larynx resulting in partial respiratory obstruction

All routine laboratory studies were normal Admission chest films showed blunting of both costophrenic angles, but there were no other significant findings The patient required a tracheotomy shortly after admission because of laryngeal edema and was started on penicillin, 600,000 units per day, and streptomycin, 1 Gm per day He was able to tolerate a soft diet for four days At this point he suddenly began vomiting ingested food through the tracheotomy tube Oral feeding was stopped and Levine tube feedings were then attempted This caused regurgitation through the tracheotomy However, we were able to pass the tube through the pylorus and in this position, most of the feedings were retained We were able to maintain nutrition and fluid balance fairly well with

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From the Thoracic Surgery Section Veterans Administration Medical Teaching Group Hospital

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daily supplements of intravenous fluids and frequent transfusions The patient easily learned to suction himself and was no problem from the standpoint of retained secretions

On April 22, 1953, esophagoscopy and bronchoscopy revealed a well epithelized fistula about 1½ inches above the tracheal carina. This was felt to be well below the lowest extent of the tracheotomy tube and almost certainly due to the original trauma On April 28, 1953, the fistula was closed (Fig 2) A right lateral approach through the bed of the fourth rib gave excellent exposure and allowed easy closure of the trachea and esophagus after separation. One row of 000 braided silk sutures was used to close the trachea and two rows of the same material were used to close the esophagus Pleural flaps were used to cover both closures.

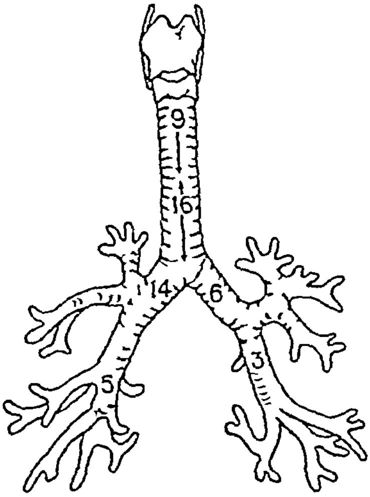

Fig 1 —Anatomic location of esophagotracheobronchial fistula in fifty-three reported cases.

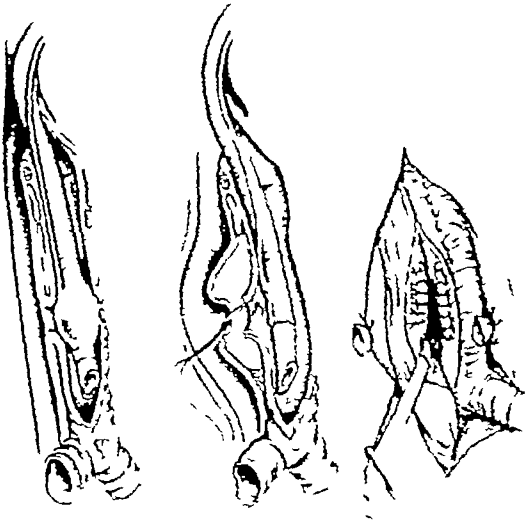

Fig 2 —Anatomic situation and method of repair in Case 1

The patient had an entirely uneventful course postoperatively. The tracheotomy tube was removed on the second day and the defect closed spontaneously within a week. A Levine tube was left in the esophagus for forty eight hours and then removed, after this the patient was able to eat a progressively expanded diet. He rapidly regained preoperative weight and has returned to work.

CASE 2.—W. McC. (VAMTG, 84 341) was a 34 year old Negro man who was admitted on April 30, 1953. He complained of periumbilical pain eight hours before admission and vomiting one cupful of dark blood. He had experienced this pain on several previous occasions but apparently no other symptoms. The patient was very feeble minded and no further history could be elicited.

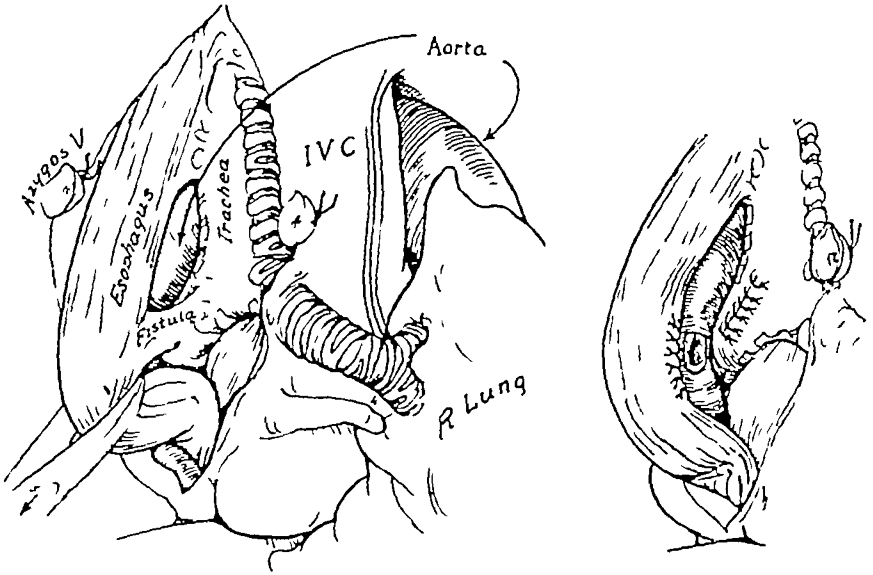

Fig. 3.—Anatomic situation and method of repair in Case 2.

Physical examination revealed an undernourished acutely ill man. Temperature was 100° F. and pulse 90. The pharynx was inflamed and partially covered with a whitish membrane. Hemogram was normal except for a 17,300 white blood count. Throat culture revealed a streptococcus and *Staphylococcus aureus*. No diphtheria bacilli were present. Sputum culture revealed a streptococcus and Friedlander's bacillus. Chest x-ray examination on admission was negative. The patient was placed on penicillin therapy and the pharyngitis promptly cleared. One week after admission he again began to vomit. Temperature spiked to 104° F. and a chest film showed pneumonitis at the left base. Vomiting occurred only immediately after eating. A Levine tube was passed and he was fed successfully via this tube. Aureomycin was added to the antibiotic therapy and the pneumonitis completely cleared by May 21, 1953. On May 24, 1953, a barium swallow with a small amount of thin solution revealed a tracheoesophageal fistula. The patient was bronchoscoped and what appeared to be a large fistula without any granulating surfaces was seen at the origin of the left main bronchus.

As the patient appeared at this time to be in fairly satisfactory condition we decided to proceed with repair of the defect. The fistula was exposed through the bed of the right fourth rib. It was freed up and closed as shown in Fig. 3. There was considerable inflammatory reaction around the fistula and, as shown, there was an ulceration which could not be freed from the arch of the aorta. We finally achieved what was thought to be a satisfactory closure.

During the first postoperative twenty four hours, the patient coughed up a great amount of mucus On the next day he improved enough so that we removed the Levine tube although feedings were not started On the third postoperative day he suddenly began coughing up bile stained fluid which also drained from the thoracostomy tube The right lung collapsed completely and an extensive pneumonitis developed on the left side Tracheotomy was done and several transfusions were given A Levine tube could not be made to pass through the esophagus and the patient was far too ill to risk esophagoscopy He became rapidly moribund and expired on June 3 1953 Autopsy showed complete disruption of both suture lines together with atelectasis of the right lung and an extensive chemical pneumonitis of the left lung

TABLE I ETIOLOGY 84 REPORTED CASES OF ESOPHAGOTRACHEOBRONCHIAL FISTULA*

Traumatic	25
Undetermined	18
Tuberculosis	14
Diverticulum of esophagus	12
Syphilis	11
Broncholiths (?)	2
Empyema	1
Actinomycosis	1

*Includes authors two cases

TABLE II. ETIOLOGY 25 REPORTED CASES OF TRAUMATIC ESOPHAGOTRACHEOBRONCHIAL FISTULA

Nonpenetrating wound	6
Foreign body	4
Dilation of stricture	4
Chemical (lye)	2
Penetrating wound	2
Operative	2
Extrapleural Lucite plombage	1
Incomplete data	4

TABLE III SURGICAL TREATMENT IN 31 REPORTED CASES OF ESOPHAGOTRACHEOBRONCHIAL FISTULA

TREATMENT	NO CASES	RESULTS		
		CURED	UNCHANGED	DIED
1 Cauterization (endoscopic)*				
A Chemical	5	4	1	0
B Electric	1	0	1	0
Total	6	4	2	0
2 Direct surgical repair				
A With preliminary gastrostomy	4	4	0	0
B Without preliminary gastrostomy†	10	7	0	3
Total	14	11	0	3
3 Pulmonary resection and closure of defect	5	4	0	1
4 Palliative gastrostomy	3	0	2	1
5 Drainage coexisting lung abscess	2	2	0	0
6 Jejunal loop bypass (lye stricture of distal esophagus)	1	1	0	0
Over all total	31	22	4	5

* All small fistulas

†Includes authors cases

COMMENT

The first case is of interest in that it demonstrates that nonpenetrating trauma can cause an esophagotracheal fistula, the clinical appearance of which may be delayed several days. Stevens[5] reported a similar case. The previous observation[3, 4] that feedings placed in the stomach are not well tolerated by these patients was confirmed. Partial feedings were possible with the tube placed well beyond the pylorus, although the feeding had to be given very slowly, lest regurgitation occur.

Several lessons were learned from the second patient. First, the presence of ulceration at the fistula site should have contraindicated surgery, had it been recognized preoperatively. This failure argues for a most meticulous endoscopic examination of the fistula from both sides, preferably with optical equipment. Second, the vigorous postoperative coughing exhibited by this patient was, in our opinion, at least partially responsible for the disruption of the suture lines. Since tracheotomy is helpful in obtaining healing after other tracheal repairs, it would seem properly indicated in a case such as this, particularly since it prevents a high air pressure from being exerted upon the suture line. Third, although tube feedings were retained fairly well by this patient, it is felt that in view of the rather debilitating illness, preliminary jejunostomy might have been preferable. Vigorous preoperative alimentation might have influenced the outcome. Removal of the Levine tube was followed quickly by desire to have it back in place at a time when it was impossible to replace it, suggesting that all should be well for several days before abandonment of gastric decompression. As to etiology, Case 2 was classified as undetermined, as the infection present on admission could not be definitely implicated as the cause of fistula.

The surgical approach through the bed of the fourth rib gave excellent exposure in both cases and permitted the fistulas to be easily mobilized. Closure of the defects was effected without great difficulty, and respiration was maintained by passing the intratracheal tube beyond the defect (Fig. 2).

SUMMARY

1. Nine new cases, including two of ours, are added to the seventy-five collected cases of esophagotracheobronchial fistula previously reported by Coleman and Bunch.

2. Two case reports are given together with a discussion of the significant features of each.

3. The factors responsible for the unsuccessful outcome in the second case are discussed.

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A SIMPLIFIED THORACIC SUCTION UNIT

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FOLLOWING thoracic surgery it is often desirable to apply negative pressure to the pleural cavity. Commonly this is done by the use of a small suction pump and two large glass jars: one of the jars is used to collect the fluid from the chest, while the other, through the use of an underwater escape tube, is used as a regulating valve. By varying the length of the escape tube submersed the amount of suction applied is regulated. Such an arrangement is excellent as far as functioning and safety go, but is very cumbersome, difficult to transport, and often loses water through the escape tube when the patient, by coughing builds up the air pressure to a point higher than the pump can accommodate.

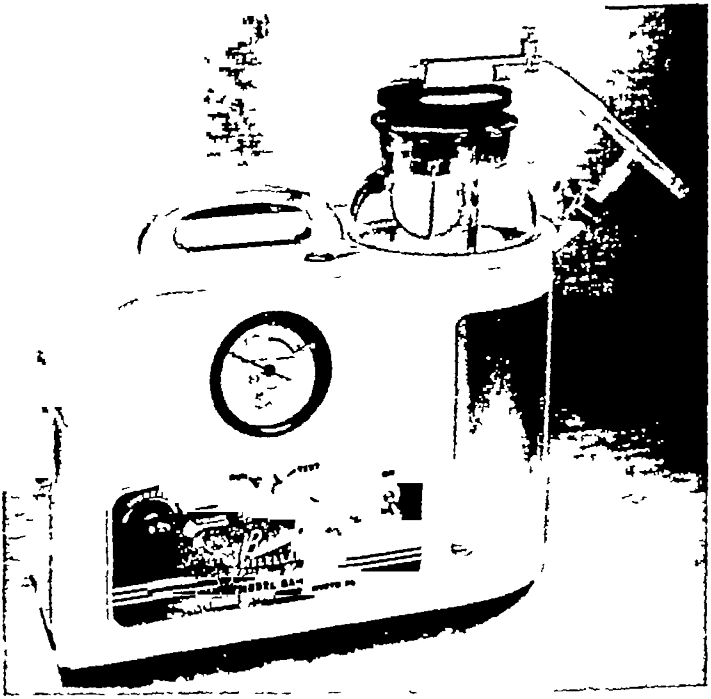

Fig. 1.—Pump unit; see text for description.

Recently a new nasogastric type suction unit containing a pump, gauge, regulating valve, and collecting bottle, all in a small metal case that weighs only 10 pounds has become available (Fig. 1).* It has been used to provide thoracic

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*The unit described is the Burdick SA-1 McClellan Suction Unit manufactured by The Burdick Company, Milton, Wis.

cavity suction with very satisfactory results Other advantages, besides its completeness compactness, and lightness in weight, are 1 The gauge is in the system at all times, so that the amount of negative pressure being applied registers constantly 2 There is a safety float in the collecting jug, which automatically prevents fluid from reaching the gauge or pump 3 The regulating mechanism is so constructed that the desired amount of suction can be set prior to connecting the pump to the drainage tube 4 The collecting container can be emptied without disconnecting the tubing

Three minor disadvantages are present in the unit They are 1 The gauge is calibrated in mercury instead of water 2 It is difficult to visualize the fluid in the collecting jar 3 The jar is not calibrated However, the manufacturer, on being informed of these faults, immediately rectified them The newer models will have (1) the gauge calibrated in both centimeters of water and millimeters of mercury, (2) the metal case will have multiple fenestrations to allow better visualization of the collected fluid and (3) the container will be calibrated in ounces and cubic centimeters

SUMMARY

A lightweight easily portable suction unit that is suitable for postoperative thoracic suction is described

PULMONARY TORULOSIS COMPLICATING PULMONARY TUBERCULOSIS TREATED BY RESECTION

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A REVIEW of the literature[1-18] has failed to disclose living patients with tuberculosis combined with torulosis, the appearance of a case is of sufficient interest to deserve mention. Stoddard and Cutler,[19] in 1916 were the first to describe accurately the clinical and pathologic characteristics of torular infection in man. Following the work of these observers, the disease received more general recognition and cases were reported from practically all parts of the world.

In 1931, Freeman[20] published a comprehensive monograph on the subject and at that time was able to collect forty-three cases of torular infection from the literature. In 1937, Taber[17] stated that to date there had been less than sixty cases of torular infection in man reported in the entire world. He also stated that the symptoms were varied depending upon the part of the body which was attacked, but they always delayed in appearance because of the insidious onset of the condition.

In the lungs, the roentgenogram may suggest inflammatory disease or neoplasm. A cough develops with little or no fever or few if any night sweats; there is some pain in the chest, malaise, and loss of weight. In 1951, Cook[4] reviewed the literature and found two hundred cases of torula reported to date. Of this number, only five cases of solitary lung involvement were recorded. In 1952, Berk and Gerstl[22] reported a case of solitary pulmonary torulosis simulating tumor in which a lobectomy was done. They also reported the five other cases found in the literature as reported by Cook. Baker,[23] in 1952 reported three patients with pulmonary cryptococcosis that had round, solid lesions varying in size from that of a plum to that of an orange. All three patients underwent resection and were alive nine months, nine and one half months and four years after operation. These three cases would seem to indicate that the resection of pulmonary cryptococcosis (torulosis) is effective. Perhaps resection was prophylaxis against the development of cryptococcosis of the central nervous system. Froio and Bailey[21] reported a case of cryptococcosis of the lung cured by lobectomy; the patient was alive seven years following surgery.

CASE REPORT

First Admission.—J. R. W. was a 19 year old married white man; he was first admitted to Battey State Hospital on Jan. 15, 1951. The diagnosis was pulmonary tuberculosis, moderately advanced (Fig. 1). The patient gave a history of having an acute illness in August, 1950 which was diagnosed as virus pneumonia. Following this he had had moderately severe fatigue which lasted without apparent change until Oct. 7, 1950. At the

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From Battey State Hospital.

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*Resident in Thoracic Surgery.

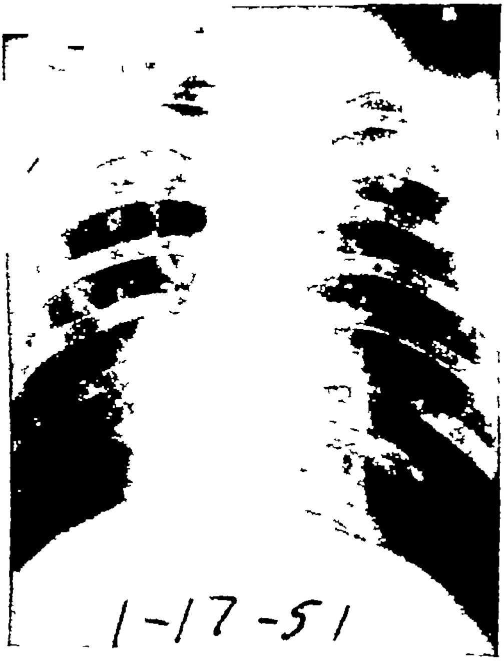

Fig 1 —Admission roentgenogram taken Jan 17 1951

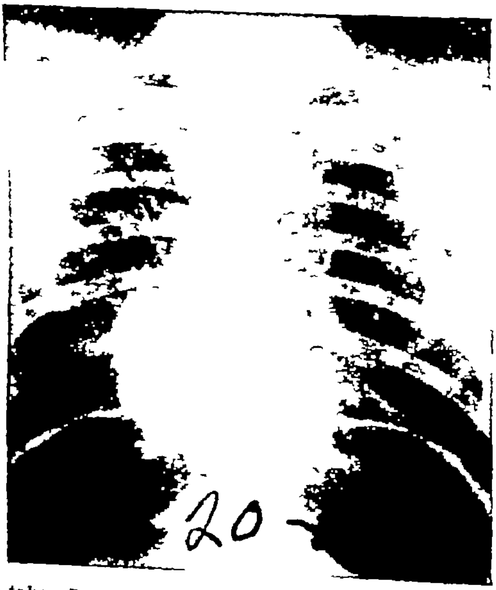

Fig 2 —X ray picture taken Sept. 20 1951 Improvement on bed rest antibiotics and pneumoperitoneum is shown

of illness he had bloody expectoration on two successive mornings He had never had any previous sputum production or cough He was hospitalized for five days in October during which time an x ray film was taken, the report indicated that a diagnosis pulmonary tuberculosis was suspected

A survey x ray examination in 1948 was reported negative Sputum examination on Oct 8, 1950, was reported as positive for acid fast bacilli The patient had lost eight pounds over the three month period, from August to October 1950

The patient s only known exposure to tuberculosis occurred in 1948, at that time he had been exposed to a fellow worker in a shoe factory for three months before the other worker was discovered to have pulmonary tuberculosis

Physical examination was complete and noncontributory

An admission x ray film dated Jan 17, 1951, was interpreted as follows "No definite infiltration is recognized in the right lung, although rather heavy markings are noted near the second interspace The left lung shows dense and moderately dense, soft scattered shadows of infiltration from the apex to the fourth interspace Classification The appearance is that of moderately advanced pulmonary tuberculosis "

The laboratory work was noncontributory except for one positive direct smear on Feb 2 1951 Subsequent cultures were positive for typical, acid fast organisms on three occasions Tuberculin test was 1 plus to 0 01 mg of old tuberculin

A bronchoscopy on Feb 2, 1951, showed the right side to be negative The left upper lobe orifice was somewhat redder than the remainder of the bronchial mucosa although there was no edema, ulceration or tubercle formation The mucosa did not bleed upon manipulation and the bronchus showed no degree of stenosis The remainder of the left side was within normal limits and the impression of the bronchoscopist was that this was probably a low grade tuberculous endobronchitis

This patient was started on a course of streptomycin (1 Gm every third day) and PAS (10 Gm daily) for a period of six months on Feb 3, 1951 Pneumoperitoneum was instituted on Feb 6, 1951

During the ensuing nine months this patient showed progressive roentgenologic improvement of the disease with bed rest, antibiotic therapy, and pneumoperitoneum

He gained eight pounds and was asymptomatic, the sputum converted On Oct 9, 1951 this patient signed out against medical advice and left the hospital (Fig 2)

Interval History—The patient stated that after leaving the hospital in October 1951 he returned home where he continued to spend about sixteen hours out of each twenty four in bed He received pneumoperitoneum refills once each week receiving 900 c c of air at each refill He denied any illness or accident after returning home He had had an x ray examination of his chest every three months since going home The sputum was reported negative in February, 1951 X ray examination of the chest revealed a change and for that reason sanatorium admission was again sought for this patient

Second Admission—This 21 year old patient was again admitted on June 12 1952 Fig 3 shows the change that had taken place in the disease while at home

Physical examination was again noncontributory

Laboratory work was entirely negative including repeated sputum examination which were consistently negative for acid fast bacilli including animal inoculations and cultures of gastric contents

A diagnostic bronchoscopy of Aug 4 1952 was negative as was a bronchogram

On Aug 4 1952 this patient was seen in surgical conference The [illegible] cm mass located in the second anterior interspace on the left side was believed to be an area of fibrocaseous tuberculosis Roentgenologically it was thought to be located in the superior division of the left lower lobe

Since admission on June 12 1952 he had been negative to direct smear culture and animal inoculation for acid fast bacilli He was accepted for surgical excision of the tuberculoma

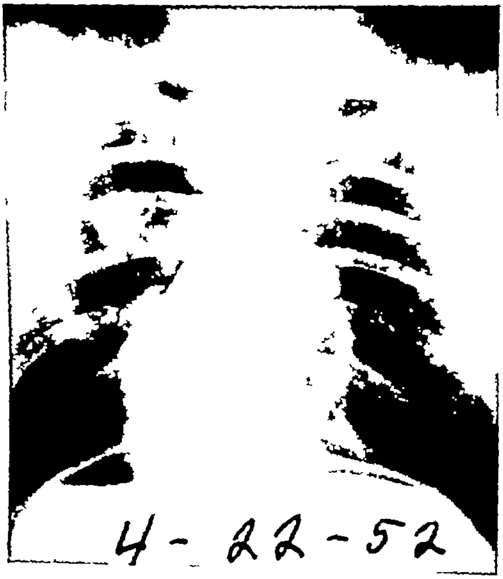

Fig 3—Roentgenogram showing change that occurred since Sept. 20 1951

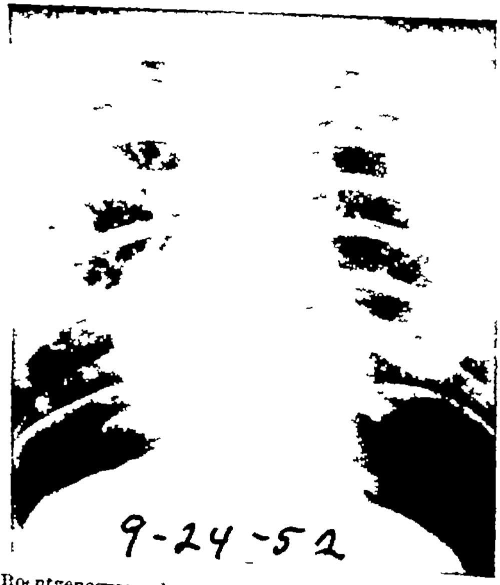

Fig 4—Roentgenogram showing excavation of previously solid lesion

Because of a long waiting list this patient was not transferred to the surgical s for the contemplated surgery until March 11, 1953. In the meantime it can be seen that th solid lesion had excavated.

In spite of the solid lesion excavating and becoming a cavitary lesion, the sput cultures of Nov. 10, 1952, and Jan. 21, 1953, were negative to direct smear and culture f acid fast organisms. The significance of this was not fully appreciated and no furth studies were done at that time.

On March 24, 1953, this patient had an exploratory thoracotomy on the left side. No free fluid was encountered. There were seven relatively lengthy and avascular adhesi binding the apical posterior segment of the left upper lobe to the parietal pleura, as well as

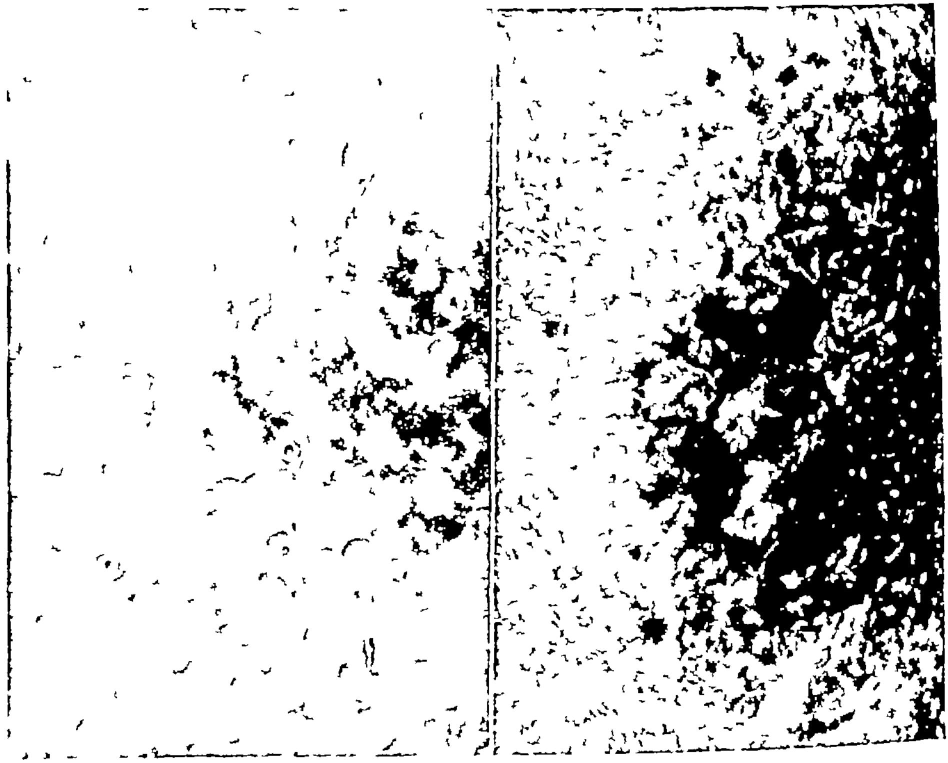

Fig. 5.—Photomicrographs showing torulosis.

a few adhesions going up to the cupula. A complete fissure line was present. By inspection and palpation, the left upper lobe revealed no appreciable evidence of induration or nodular formation. There was a definite circumscribed, 2 cm. mass in the superior segment of th left lower lobe. Elsewhere the lung was free from palpable or visible lesions. A subsegmental type of resection was carried out.

The preoperative diagnosis was pulmonary tuberculosis and we still felt, postoperatively that this was a tuberculous lesion.

Pathology.—

The gross description is as follows:*

"Received is one small round nodular sub-segment of the superior division, left lower lobe, measuring 2 x 1½ x 1½ centimeters and weighing 2½ grams. The external surfac is circumferentially roughened and reveals brownish red parenchyma without pleura. On

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*Given by Dr. Ingrid Stergus, Pathologist at Battey State Hospital.

CONGENITAL CYSTIC LUNG

Successful Pneumonectomy in a 3 Week Old Baby

G Gordon Crowe, M B , Ch B , F R C S Ed *
Newcastle-under-Lyme, England

SOME congenital cysts of the lung may only be discovered accidentally during a routine examination of the chest However, there are two sorts of complications which may give rise to trouble in congenital cystic lung

In the first place infection of the cyst may occur and this may be fatal, second, due to a ball valve action, very high positive pressure may be built up within the cyst so that it becomes greatly distended, compressing the adjacent lung tissue and displacing the mediastinal organs to the opposite side of the chest Unless prompt treatment is carried out to relieve the respiratory distress, a fatal result may ensue

In the case reported here, congenital cystic lung in a 10 day old baby did indeed give rise to great respiratory distress which did not react to simple measures like the needling of the cyst cavity Eventually, when the baby was 23 days old, a left pneumonectomy had to be carried out

CASE REPORT

M R was admitted to hospital on April 18, 1952, she was 15 days old with a history of being cyanotic and dyspneic for three days On examination the child was dyspneic and was cyanotic Temperature was normal, pulse was 160, and respirations were 54 The heart was located to the right of the lower end of the sternum and there did not appear to be any air entry on the left side of the chest X ray films of the chest showed that there were numerous cysts in the left lung and the heart was displaced to the right (Fig 1)

Needling of a larger cyst was carried out, and this cyst was shown to have a positive pressure of 15 cm when measured with an artificial pneumothorax apparatus An underwater drainage system was connected to a pneumothorax needle The patient was treated by the pediatrician with repeated needling and underwater drainage until I was asked to see her on April 26, 1952

It was obvious that the needling was resulting only in a temporary improvement and so on April 26, 1952, a thoracotomy was carried out through the bed of the fifth left rib when the child was 23 days old On opening the pleura the upper lobe was found to contain a very large cyst which was filled with air and appeared to have a large communication with the bronchus The lower lobe also contained several fairly large cysts An upper lobectomy was carried out, but after this procedure, when the anesthetist attempted to inflate the lower lobe it was found that that lobe would not inflate In view of this fact and because it was felt that the cysts in the lower lobe would almost certainly give rise to trouble at a later date, the operation was converted into a left total pneumonectomy The pleural cavity was drained by a 5 c c Foley catheter During the operation and during the postoperative period, the child had 450 c c of Hartmann solution and about 50 c c of blood She was given, after the operation, streptomycin (70 mg twice a day) and a course of Chloromycetin

She made a satisfactory recovery after operation but the convalescence was complicated by discharge from the stab wound which persisted for about six months before it finally cleared up The wound has now been dry for two months

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*Consultant Surgeon City General Hospital Stoke on Trent.

This is the only instance we have been able to find after an extensive review of the literature, showing cryptococcosis and pulmonary tuberculosis in a living patient, who had either or both of the lesions treated surgically

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CONGENITAL CYSTIC LUNG

SUCCESSFUL PNEUMONECTOMY IN A 3-WEEK-OLD BABY

G GORDON CROWE M B CH B F R C S ED*
NEWCASTLE-UNDER-LYME, ENGLAND

SOME congenital cysts of the lung may only be discovered accidentally during a routine examination of the chest However, there are two sorts of complications which may give rise to trouble in congenital cystic lung

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M B was admitted to hospital on April 18, 1952, she was 15 days old with a history of being cyanotic and dyspneic for three days On examination the child was dyspneic and was cyanotic Temperature was normal pulse was 160 and respirations were 54 The heart was located to the right of the lower end of the sternum and there did not appear to be any air entry on the left side of the chest X ray films of the chest showed that there were numerous cysts in the left lung and the heart was displaced to the right (Fig 1)

Needling of a larger cyst was carried out, and this cyst was shown to have a positive pressure of 15 cm. when measured with an artificial pneumothorax apparatus An underwater drainage system was connected to a pneumothorax needle The patient was treated by the pediatrician with repeated needling and underwater drainage until I was asked to see her on April 26 1952

It was obvious that the needling was resulting only in a temporary improvement and so on April 26, 1952 a thoracotomy was carried out through the bed of the fifth left rib when the child was 23 days old On opening the pleura the upper lobe was found to contain a very large cyst which was filled with air and appeared to have a large communication with the bronchus The lower lobe also contained several fairly large cysts An upper lobectomy was carried out, but after this procedure, when the anesthetist attempted to inflate the lower lobe it was found that that lobe would not inflate In view of this fact and because it was felt that the cysts in the lower lobe would almost certainly give rise to trouble at a later date the operation was converted into a left total pneumonectomy The pleural cavity was drained by a 5 c c Foley catheter During the operation and during the postoperative period the child had 450 c c of Hartmann solution and about 50 c c of blood She was given after the operation, streptomycin (70 mg twice a day) and a course of Chloromycetin.

She made a satisfactory recovery after operation but the convalescence was complicated by discharge from the stab wound which persisted for about six months before it finally cleared up The wound has now been dry for two months

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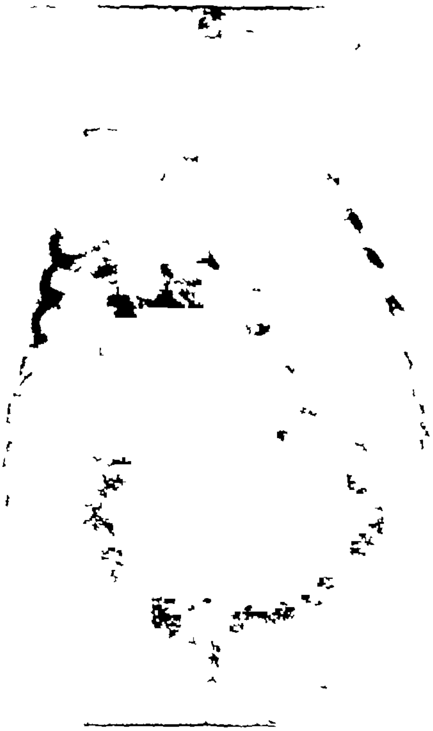

Fig 1

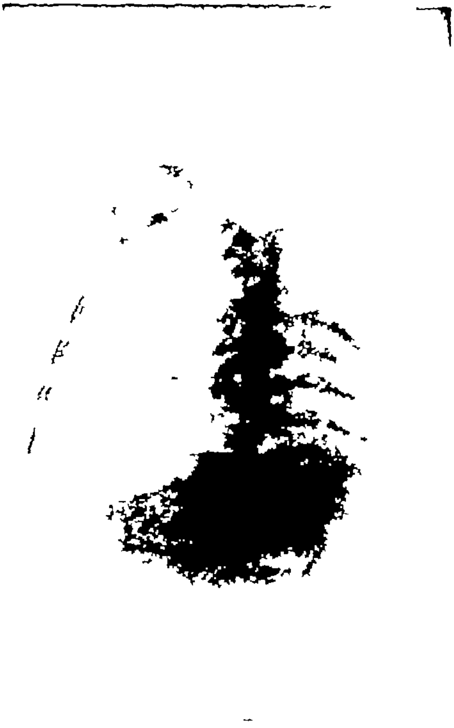

Fig 2

Fig 1.—X-ray film shows numerous cysts in the left lung and displacement of the heart to the right.

Fig 2.—X ray picture taken eleven months after operation showing that the heart is not now displaced to the right.

Fig 3.—Photograph showing appearance of child at the age of 11 months

Eleven months following operation the child's condition was very good (Fig 3) She eats normally, weight is normal for a child of her age There is no deformity of the thoracic cage and there is no scoliosis of the spine present X ray films now show no displacement of the heart shadow (Fig 2)

The pathologic report on the lung was that both lobes showed small thin walled multiple cysts varying from 1 mm to about 5 mm. in diameter The cysts were more numerous at the periphery than at the center of the lobes One or two large, thin walled cysts lying immediately below the visceral pleura had already ruptured The cysts were lined with cuboidal, columnar, and ciliated epithelium and they appeared to communicate with the bronchi. This would appear to be a case of congenital cystic disease of the lung

The youngest patient to date to have a pulmonary resection was a 15-day old baby, who was treated by Burnett and Caswell This child was admitted to hospital with marked dyspnea X-ray examination showed multiple loculations of air in the left side of the chest which appeared to involve the entire hemothorax and displace the mediastinum markedly to the right The child was diagnosed as having a congenital left diaphragmatic hernia, and when she was 14 days old laparotomy was performed At operation it was found that both diaphragms were intact, it was then realized that the child was suffering from congenital cystic disease of the left lung The next day thoracotomy was performed, the left upper lobe was normal, and she was, therefore, treated by left lower lobectomy

Gross, in December, 1944, carried out a left pneumonectomy in a 23 day-old baby for congenital cystic disease The remarkable ease with which lobectomy and pneumonectomy can be done in infants was noted again in this patient It has previously been described by Fischer and his co-workers, by Gross, and by Burnett and Caswell Dissection of the structures in the hilum is remarkably simple and can be rapidly carried out

My thanks are due to Dr J G Dathan for referring this case to me, to Dr C Hayes for the anesthesia, to Dr C Giles for the pathologic report, and to Dr J White for the x ray photographs

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BLOOD LOSS AND ITS REPLACEMENT IN THORACIC SURGERY

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THE large blood loss that accompanies major surgery of the chest is obvious to all observers of such operations. In fact, the present state of development of thoracic surgical techniques would not be possible without the availability of adequate amounts of blood for infusion. The amount of blood given during the course of surgery is usually based upon estimates of blood loss by the surgeon and the anesthetist derived from evaluation of the condition of the patient and observation of discarded sponges.

That such methods are open to wide individual variations can be shown by the wide divergence of estimates of total blood loss given by individual members of an operating team. Such a significant variation in the estimated blood loss led us at the West Tennessee Tuberculosis Hospital to adopt the sponge weight method of measuring blood loss as described by Gross[1] and by Johnson and Kirby,[2] among others. The dry sponges were weighed in sufficient number to obtain an average weight for one sponge although the range was small. At operation the sponges are weighed on a dietetic scale as they are discarded, the dry weight subtracted, and the remainder counted as blood, assuming that 1 Gm. equals 1 c.c. of blood. Saline for irrigation is used in measured quantities, and the amount used is subtracted from the volume of the contents of the suction bottle. Wet pads are not used. Finally, an estimated volume is added to the total to account for the blood on the drape sheets.

Although this technique is admittedly not accurate enough for exact experimental measurements of blood loss, it is simple and rapid and is not subject to gross error. The circulating nurse can add this task to her duties without difficulty. A running tally of the blood loss is kept and the blood is replaced as it is lost. The amount of blood given in the postoperative period is governed by the amount and quality of drainage and the condition of the patient.

METHODS AND MATERIALS

For the purpose of this study every major thoracic surgical procedure done at the West Tennessee Tuberculosis Hospital between Jan. 1, 1952, and April 30, 1953, has been reviewed. The type of procedure, the amount of blood administered, and the occurrence of surgical shock and mortality have been noted. A total of 412 consecutive procedures is included. In 196 of these

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the blood loss was measured by the sponge weight method previously outlined In 216 the blood loss was estimated and replaced as considered necessary in the operating room and in the immediate postoperative period

A few operations are not included such as the revision of chest wall sinuses and thoracotomy drainage procedures In the 412 operations, there has been one death This occurred five days after a first-stage thoracoplasty done over a pneumonectomy space The patient, an obese Negro man 44 years old, was in respiratory distress from the time of surgery and died on the fifth day A widespread disseminated tuberculosis was present, together with an unsuspected cor pulmonale One death occurred twelve hours after completion of a pneumonectomy About one hour after surgery the patient suddenly went into profound shock and developed massive interstitial emphysema Intercostal drainage was instituted, blood in large quantities was removed and transfusions started in three veins The blood pressure responded promptly, but the patient lapsed into coma Convulsions occurred and death followed in eight hours Autopsy could not be obtained, but it is speculated that some cerebral embolic episode must have occurred This case is not included in the analysis, because as the blood was given some was spilled, moreover, some blood was strained and given back after aspiration from the chest The figures are valueless

Two patients who had lobectomy are also excluded since both had postoperative bleeding requiring secondary surgery One of these patients received nineteen transfusions (9,000 c c of blood) in the forty-eight hours during and immediately after surgery, and the other patient received twelve transfusions (5,750 c c) Both patients recovered It was decided that these two cases would unduly distort the average figures

One patient who had decortication of an old tuberculous empyema received a total of 7,500 c c of blood He finally succumbed to repeated exsanguinating episodes, apparently related to operative injury of mediastinal vessels

With these exceptions the operations analyzed here include all cases done on the surgical service at the West Tennessee Tuberculosis Hospital during the sixteen months ending April 30, 1953 There is considerable overlapping in the series since the sponge weighing at first was somewhat irregular, being done only on specific request of the operating surgeon A total of ten different surgeons both residents and staff surgeons, operated on the service during the period under discussion

In Table I, the 196 operations are listed in which blood loss was calculated by the sponge weight method There are 90 thoracoplasty procedures of three stages Some of the first- and second stage procedures were done after pulmonary resections, while others were primary thoracoplasties, either of the Alexander type or similarly staged operations In all three procedures, approximately 300 c c appears to be the minimum blood loss by our technique The maximum is extremely variable

TABLE I BLOOD LOSS IN CERTAIN THORACIC OPERATIONS AS MEASURED BY SPONGE WEIGHT METHOD

OPERATIVE PROCEDURE	NO OF CASES	BLOOD LOSS RANGE IN C C	BLOOD LOSS AVERAGE
Thoracoplasty, Stage I	55	335 1,708	932
Thoracoplasty, Stage II	23	329 1,360	788
Thoracoplasty, Stage III	12	300 900	556
Pneumonectomy	17	400 2,930	1,051
Lobectomy	43	329 3,066	1,153
Segmental resection	19	360 1,430	814
Lobe and segment decortication lobe and decortication	20	899 2,403	1,340
Miscellaneous	7	325 2,000	752

The remaining 106 procedures were intrapleural operations of varying magnitude Those included under the heading "Miscellaneous" are three pulmonary biopsies, a mediastinal cyst two exploratory operations in which inoperable carcinoma was encountered and one aortic aneurysm packed with wire The minimum operative blood loss is around 325 c c while the maximum ranges up to 3066 in one particularly difficult extrapleural lobectomy Again in all these procedures the wide variation among cases is noteworthy There is such a range that figures for average loss are meaningless

In Table II there is a clinical comparison between the 196 operations in which sponges were weighed and the 216 instances in which replacement was based on estimates of blood loss and evaluation of the condition of the patients The eleven operations under "Miscellaneous" include three pulmonary biopsies three exploratory operations for carcinoma three extrapleural pneumonolysis and one operation for funnel chest Systolic blood pressure below 90 mm Hg for more than thirty minutes at any time during operation or in the postoperative period was defined as shock In second stage thoracoplasty operations the amount of blood given was significantly greater in operations in the weight loss column and the percentage of surgical shock somewhat higher In first- and third-stage thoracoplasty operations the amount of transfusions used was essentially the same for the two groups while shock was much more frequent in the patients in whom blood loss was not weighed

TABLE II CLINICAL COMPARISON BETWEEN OPERATIONS WITH BLOOD LOSS WEIGHED AND ESTIMATED

	BLOOD LOSS WEIGHED				BLOOD LESS ESTIMATED			
		BLOOD GIVEN	SHOCK			BLOOD GIVEN	SHOCK	
OPERATIVE PROCEDURES	NO	AVERAGE	NO	%	NO	AVERAGE	NO	%
Thoracoplasty Stage I	55	1,001	3	5.4	62	1,027	16	26.0
Thoracoplasty Stage II	23	817	3	13.0	26	574	2	7.7
Thoracoplasty Stage III	12	658	0	0	16	550	1	6.0
Pneumonectomy	17	1,735	0	0	20	1,811	6	30.0
Lobectomy	43	1,682	6	14.0	52	1,859	12	23.0
Segmental resection	19	1,097	0	0	14	1,525	2	14.0
Lobe and segment decortication decortication and lobe	20	1,691	0	0	15	1,653	1	7.0
Miscellaneous	7	1,000	0	0	11	590	0	0

For intrapleural operations the amount of blood given was comparable in the two groups except in segmental resections. In these cases more blood was used in the "nonweighed" group and two instances of shock were recorded. However, the number involved is too small to be significant.

Table III is a summary of the cases divided into larger groups which may possibly be of more significance. For both thoracoplasty and other procedures shock is approximately three times as common in the nonweighed than in the weighed group.

TABLE III. SUMMARY

	THORACOPLASTY PROCEDURES		OTHER OPERATIONS		TOTAL	
	CASES	SHOCK	CASES	SHOCK	CASES	SHOCK
Weighed	90	6— 6.7%	106	6— 5.7%	196	12— 6.0%
Nonweighed	104	19—18.3%	112	21—18.7%	216	40—18.5%

DISCUSSION

The clinical management of the cases presented here has been carried out by the members of the staff of the hospital in both medical and surgical departments and has been uniform throughout the period under discussion. The operative technique has not appreciably changed and the operations have been performed by the same members of the surgical staff and by residents under their direction. The only difference in the care of the patients has been the addition of the sponge weight method of blood loss determination and a more careful attention to blood replacement at the time it is lost. For these patients the measurement of blood loss has been of value. It may be that the emphasis on blood loss has resulted in more adequate hemostasis and that the patients have actually lost less blood than those in whom definite figures for blood loss are not obtained. Over such a long time and with so many surgeons involved this does not seem likely. Emphasis is constantly placed on the importance of keeping up with the blood loss. The patient returns to his room with his circulating fluid in balance. Much less blood is needed to prevent shock than to treat it after the blood pressure has fallen to low levels.

In the 412 operations catalogued here the total blood used amounted to 516,750 c.c., the equivalent of 1,033 transfusions of 500 c.c. each. This blood was used in sixteen months on one thoracic surgical service. The figure does not include transfusions administered preoperatively or those used on the medical services of the hospital. There are also a few operations not included. It is re-emphasized that an active chest surgery service depends to a great extent on an adequate blood bank.

SUMMARY

A study of blood loss and its replacement during operations on the chest has been presented with 412 major surgical procedures included in the statistical analysis. The method of measurement as outlined seems accurate enough for practical purposes and has the virtues of simplicity and economy. The advantages of measuring and replacing blood loss as it occurs is borne out statistically and measured by a significantly decreased incidence of surgical shock in the group of patients in whom this was practiced Hemostasis is constantly emphasized to the operating surgeons by the periodic announcement of weighed blood loss

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THE PROBLEM OF THE FAR-ADVANCED MALIGNANCY IN THE UPPER ESOPHAGUS

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CARCINOMA of the upper esophagus continues as a formidable scourge and remains a challenge to the physician but offers a very poor prognosis to the patient. The articulate exponents of radical deviscerating surgery, in popularizing their technique for this or any far-advanced malignancy, often leave in their wake a host of problems. The surgeon attempting to emulate these venerable scientists frequently finds himself beset with discouraging and alarming results. The high operative mortality, the few survivors at the end of a year, and the marked disturbance in digestive physiology are sufficient reasons for a closer inquiry and evaluation into the philosophy of extreme and radical surgery in carcinoma of the upper esophagus.

In any form of therapy the benefits accruing from its use must be weighed against its mortality and morbidity. While in our small series of nineteen cases there were no anesthetic deaths and only one operative death, the literature is nevertheless replete with them. What is more important is the fact that in our series no patient survived more than sixteen months, and a similar picture has been observed in practically all clinics.

These individuals with upper esophageal malignancy primarily seek relief from their inability to swallow. This extreme difficulty, coupled with an urgent desire to eat, provokes them into undergoing almost any type of surgery for relief. After enduring a most difficult, trying and serious operation the patient finds himself able to swallow food but without any desire to eat. Food becomes tasteless and its ingestion is frequently associated with substernal spasm or regurgitation. Does an end result producing such an unhappy physiologic cripple warrant the extensive deviscerating surgery?

In view of the dubious symptomatic relief and seeming incurability of this lesion, it is incumbent upon the surgeon to advise the patient or his family relative to the type of surgery indicated. The more malignancy of the esophagus is observed the greater becomes the desire of the surgeon simply to relieve the symptoms and resort to radical surgery only in ideal cases where a chance for cure is reasonably good. Thus radical resection of the esophagus should be undertaken in early localized lesions and palliative procedures employed where the lesion is fixed to adjacent organs or where wide lymphogenous spread is evident.

However, the discovery of early malignant esophageal lesions at present is truly a rarity and usually due to fortuitous circumstances. This is demonstrated in the review of our case histories; symptoms have been present from three months to two years with many of the patients unable to swallow both solid

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and liquid foods Thus, the average patient coming to the surgeon had moderate to far-advanced carcinoma of the upper esophagus, which on occasions was solidly fixed to the aorta, lymph nodes, bronchi, and other mediastinal organs Our present approach, therefore, is an inadequate one for the curing of early lesions

The medical profession would do well to be on the alert and support any new adequate screening test which may be developed for malignancy Until such a screening test is developed, accidental discovery will be our only source for detecting small localized lesions which ordinarily provide us with five-year cures At the same time, both the layman and the physician should appreciate their responsibility, for frequently either one or the other has neglected to determine the cause of a progressive dysphagia Certainly any individual with a difficulty in swallowing deserves roentgenoscopic investigation by a competent radiologist If this simple procedure were accomplished, many early lesions of the esophagus might be detected, and a reasonable percentage of cures might be expected *Even though the malignancy may be far advanced or incurable* the patient deserves the right to have relief from his symptoms, if possible, in the least hazardous manner

The patient's symptoms may be controlled in several ways If a patient is unwilling to undergo a major surgical ordeal, or the lesion is extremely far advanced, the patient can be offered a gastrostomy, the use of a small polyethylene tube, or roentgen-ray therapy The gastrostomy is mentioned only for the purpose of the strongest condemnation, since it leaves the patient in a ghastly state and existence is intolerable The insertion of a polyethylene tube introduced through the nose into the stomach may sustain a patient for months On occasion, the preliminary swallowing of a string may facilitate the introduction of the polyethylene tubing Interestingly enough, with the tube in place the swallowing mechanism seems to improve This may be due to the necrosis caused by the pressure from the tube on the tumor When improvement in swallowing is real the tube may be removed for varying periods of time until there is a recurrence of dysphagia requiring its insertion again I should like to emphasize that roentgen-ray therapy surprisingly often provides temporary relief in carcinoma of the upper esophagus This is in sharp contrast to lesions at the lower end, where little or no benefit is derived from this form of treatment

In cases in which neoplasm is localized exploratory thoracotomy offers the best hope for the control of the lesion or symptoms The surgeon can resect the diseased portion of the esophagus and perform an esophagogastrostomy However, in far-advanced lesions, when hope for a cure cannot be anticipated a short circuiting operation with the cancerous portion left intact and the stomach anastomosed to the esophagus proximal to the lesion may be preferable While no cure is anticipated with this procedure the patient can eat and remain relatively comfortable until the terminal period

It was elected to do this in four cases which were far advanced and in which the average survival time was eleven months Our surgical approach to the malignancy was through an extended incision in the right anterior third

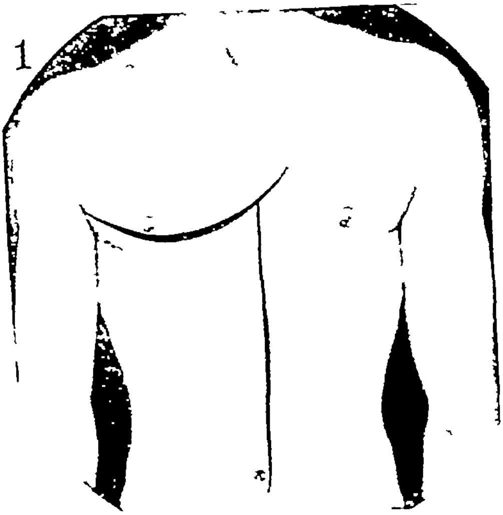

Fig 1 —A curved incision is made beginning at the left third costal cartilage extending beneath the nipple to the posterior axillary line By using a curved incision the flap can be reflected so the second third and fourth costal cartilages can be easily exposed and severed if necessary for a better exposure The midline incision is continued down the sternum and linea alba to the umbilicus The diaphragm is cut in line with the incision to the esophageal hiatus

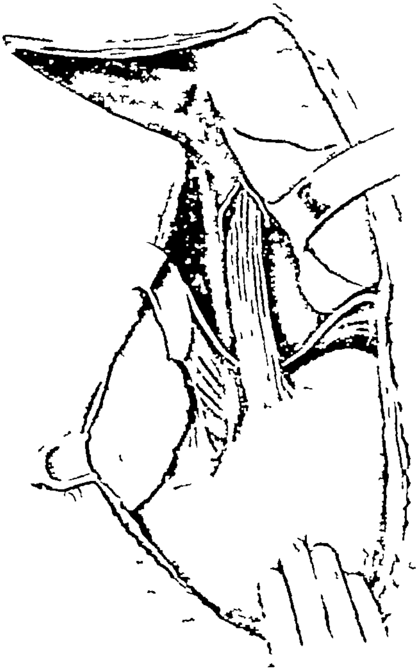

Fig 2.—This shows the lung and heart retracted to the left exposing an extensive esophageal malignancy which has invaded the surounding tissue The esophagus distal to the lesion and the stomach have been freed of their vascular attachment preparatory to delivering the stomach into the chest cavity

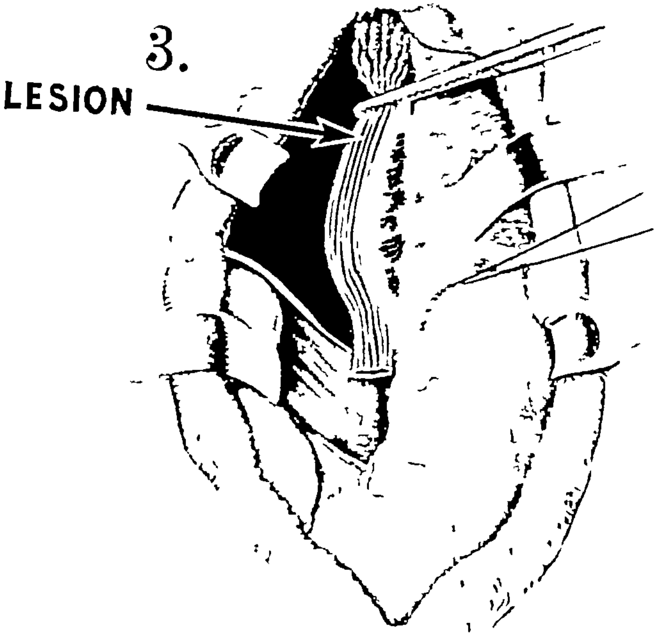

Fig 3 —The esophagus has been severed from the stomach and the cardia closed The clamp applied to the inferior border of the tumor is released and the lumen of the esophageal mass is permitted to drain into the pleural cavity

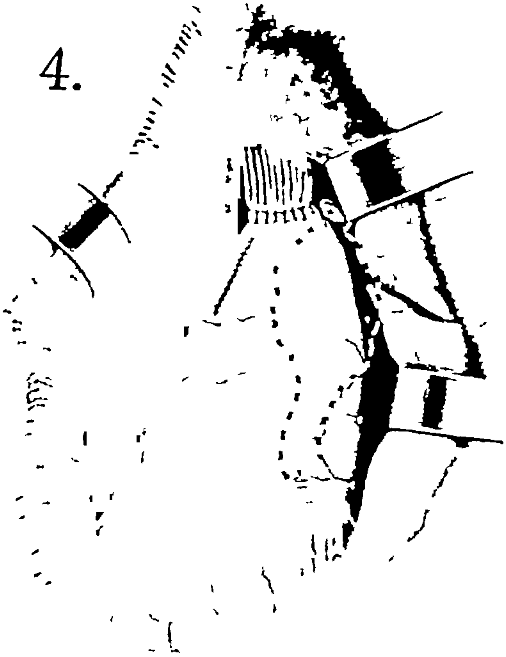

Fig 4 —The stomach is anastomosed to the distal end of the proximal portion of the sophagus above the nonresectable malignant lesion Note the stomach takes a position nterior and lateral to the tumor which is left in situ

or fourth intercostal space Dissection was carried through into the right pleural space the mediastinal pleura was divided, and the esophagus exposed The extent and the operability of the lesion could then be readily determined If definitive surgery is possible the incision is continued by spliting the sternum (Figs 1 and 2) and dividing the abdominal linea alba to the umbilicus (Figs 3 and 4)

This incision is selected for several reasons The supine position is the most physiologic one for respiration and reduces to a minimum the hazard of an increased carbon dioxide concentration in the blood Moreover through this incision, not only is the depth of the wound considerably less than with the posterolateral exposure but the esophagus and stomach are more readily exposed Furthermore in the presence of an adherent tumor there is greater danger with the left posterolateral approach of injuring or tearing the azygos vein aorta or bronchus

Another consideration is that a relatively short anterior incision is made in the diaphragm Consequently the function of the diaphragm is less impaired which is important in this age group of patients

The proposed incision also has a distinct advantage over the combined abdominothoracotomy In making the combined exposure the abdomen is first opened to free the stomach Thus the surgeon is committed to a major operation before determining the resectability of the growth In addition when the patient is turned on his side for the second stage he is exposed to the increased hazard of carbon dioxide accumulation

The disadvantages encountered by the anterior thoracotomy are (1) the need for two assistants and (2) the necessity of anteriorly retracting the lung which if not handled with care may be injured

The postoperative care of these patients is equally as important as the preoperative preparation Because of the inevitable atonia of the stomach due to the bilateral vagotomy, we prefer our patients return from the operating room with a Levine tube inserted into the stomach The drainage from the Levine tube is accurately measured, for it provides an excellent index as to the electrolyte and water loss from the upper gastrointestinal secretion Considerable amounts of sodium potassium, and chlorides may be lost in this manner and occasionally a patient may experience cardiac arrhythmia or other physiologic disturbances from these losses

The need of maintaining fluid and electrolyte balance is of the utmost importance Although the ideal supportive measures are not completely understood at the present time certain factors seem to be evident It is relatively well known that when the cells of the body are subjected to trauma, they seem to retain water and lose potassium It has been our policy to limit fluid postoperatively to 1 000 to 2 000 c c on the first and second days since there is a compensatory sodium and water retention by the body Following the first two postoperative days the patient receives a total fluid which is determined by the loss in gastric drainage in the form of Hartmann s or Ringer s solution plus 2 000 c c of 5 per cent glucose in water Therefore a patient with 1 000 c c of gastric drainage receives a daily total of 3,000 c c , consisting of 1,000 c c of Ringer's or Hartmann's solution and 2,000 c.c. of 5 per cent glucose in water. In the final analysis, the urinary output is the gauge determining whether more or less water is required by the body. With a low urinary output, highly concentrated, as shown by a high specific gravity, the total fluid administration should be increased.

The four patients in whom the lesion was left isolated and intact are reported below.

CASE REPORTS

CASE 1.—A 62 year old white man was admitted to the hospital complaining of substernal pain and progressive dysphagia of eight months' duration, with a weight loss of thirty pounds. The patient was in fair physical condition. Esophagoscopic examination and biopsy, however, confirmed the impression of carcinoma in the upper middle third of the esophagus. There was no bronchoscopic evidence of bronchial invasion.

We were confident this lesion was resectable. Inadvertently the abdominal portion of the operation was completed before determining the intrathoracic extent of the growth. A thoracotomy incision was made through the right third intercostal space. It was found that the tumor had so circumscribed the aorta that it did not appear resectable, so we proceeded with the intention of removing this mass by the "grubbing out technique." In order to obtain better exposure and facilitate removal of the tumor, the sternum was split so that the abdominal and thoracic incisions were connected. Because of the extension of the tumor into both pleural cavities with fixation to the aorta and since the patient was not doing well we were compelled to isolate the involved segment of the esophagus and leave it in situ. The stomach was then anastomosed to the proximal segment of the esophagus.

Closure of the abdominal and thoracic wounds was done in the customary manner and the sternum was reapproximated with steel wire. One intercostal drain was used and connected to a water-sealed jug. The patient developed no signs or symptoms suggestive of mediastinitis or empyema. The only disturbing postoperative complication was a drug sensitivity. He was discharged sixteen days after operation, in a fair condition. One year later the patient was in a poor state of nutrition and complaints of pain and malaise were variable and severe.

Comment.—Much surgery was done on this patient without removing the disease which will eventually kill him. When malignancy of the esophagus has progressed this far we can do very little except to alleviate symptoms but in certain cases we are justified in doing extensive surgery to accomplish even this result.

CASE 2.—A 53 year old housewife had minor symptoms of dysphagia for three months and had lost thirty-six pounds. In recent weeks even liquids were regurgitated. This patient was in a poor state of nutrition but further physical examination was not revealing. Roentgenograms showed an obstructive lesion in the upper part of the middle third of the esophagus. Esophagoscopic biopsy showed a squamous cell carcinoma. By bronchoscopy it was thought the bronchus was not intrinsically involved.

Later, through a right third intercostal incision, the mediastinal mass was found to be hopelessly nonresectable; it was intimately attached to the aorta and the posterior surface of the bronchus. The sternum was then split in the midline and the incision extended to the umbilicus and the diaphragm was opened to the esophageal hiatus. After the stomach was freed of its vascular attachments, the lower portion of the esophagus was dissected out of the mediastinum. The mass was isolated by severing the esophagus proximally and distally to the growth. The distal end of this malignant mass was left open. With the lung retracted anteriorly, the stomach was anastomosed to the proximal portion of the esophagus

The diaphragm was closed with interrupted cotton sutures Both abdominal and chest wounds were closed in the usual manner with the sternum being held in place with stainless steel wires One posterior mushroom catheter was connected to a water-sealed jug

The patient's postoperative course was interrupted by hypochloremia which was controlled with intravenous potassium chloride This patient developed no signs of intrapleural infection Under protest, she went home thirteen days after operation There were no swallowing difficulties although she had a complete anorexia and remained in a very poor nutritional state On three occasions she was readmitted to the hospital because of starvation symptoms but always refused to stay but a few days She remained bedridden and died at home six months after operation. There was no autopsy

Comment—As is true in this case we have to rationalize as to why we operate on such poor miserable souls After investigating the sociologic and economic background of this individual it was quite apparent that neither she nor her stepchildren could manage the simple feeding through a polyethylene tube However the justification of extensive surgery for only six months of miserable existence is debatable

CASE 3—A 64-year-old white man had the complaints of dysphagia for four months duration, with only eight or ten pounds of weight loss This patient was in an unusually good physical condition, as he had not undergone the usual deterioration that is seen with malignancy of the esophagus Esophagoscopic and bronchoscopic examination with biopsy established the diagnosis and disclosed fixation of the trachea at its bifurcation Upon exploration through a left thoracoabdominal incision the mass was found to be adherent to all surrounding structures and nonremovable

The stomach and the lower end of the esophagus were freed the esophagus was severed at the proximal and distal ends of the neoplasm and the stomach was anastomosed to the proximal esophageal segment Radon seeds were placed in the tumor and it was left intact The patient's postoperative course was not remarkable and he was discharged sixteen days after the operation Effler reported that this patient lived fourteen months before dying of extensive carcinomatosis

Comment—This individual was able to carry on quite well for approximately twelve months It is significant to note that even though a malignant mass with all its necrosis drained into the pleural cavity no intrapleural infection developed

CASE 4—This 64 year old white woman had swallowing difficulties ten months before seeking relief She denied much weight loss though she was poorly nourished and obviously underweight Careful preoperative conditioning on a medical regimen was required before this individual was explored through a left thoracoabdominal approach There was extensive local spread and the mass was "frozen" to its surrounding structures and was thus hopelessly nonresectable The esophagus was severed at the proximal and distal ends of the tumor after which the stomach was anastomosed to the esophagus with the lesion left in situ in the mediastinum. The patient did not develop empyema or other symptoms of intrathoracic infection. She had many electrolytic and nutritional problems after the operation but was discharged within seventeen days She survived without appetite and with substernal pain for ten months

Comment—It is most disturbing to the surgeon but even more distressing to the patient to learn that after extensive surgery he is able to swallow but unable to eat because of loss of appetite The alteration in peristalsis and the atonia of the stomach are probably the reasons for this appetite loss Urecholine given subcutaneously and orally improves the loss of appetite in some patients as we have recently experienced

SUMMARY

In summary, we would like to emphasize three points First, our present approach to the control of malignancy of the upper esophagus rarely permits early diagnosis and five-year cures Second, the heroic and radical resection of the tumor in far-advanced cases with esophagogastrostomy leaves much to be desired Third, surgeons can do very little except alleviate symptoms in cases so far advanced

Conditionally and with reservations, we have proposed a by passing operation in which the esophagus is anastomosed to the stomach and the tumor is left in situ In four such cases, no intrathoracic infection developed

Finally, we advocate x-ray-irradiation before undertaking extensive surgery, and we recommend the modified anterior thoracoabdominal incision in certain cases as described

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A CASE OF SPONTANEOUS REGRESSION OF AN UNTREATED BRONCHIOGENIC CARCINOMA

BRIAN BLADES, M.D., AND ROBERT G. MCCORKLE, JR., M.D.
WASHINGTON, D.C.

INCREASED experience with cases of bronchiogenic carcinoma has established tremendous differences in the behavior of these tumors. Some are indolent, slow-growing, well-differentiated, epidermoid carcinomas; others are rapidly progressing, entirely undifferentiated types of neoplasms.

Most experienced clinicians have observed authenticated cases of lung cancer which, over long periods of time, have not increased in size or caused symptoms. The indolent behavior of some pulmonary neoplasms, naturally, brings up the question of whether two- and three-year survivals following surgical intervention might not have depended more on the nature of the tumor than accomplishments of the operation.

The behavior of these tumors is compatible with Handley's[1] ideas expressed in 1909. He believed that every aggregation of cancer cells has a definite life cycle and that the cells might increase in size over a period of time and at a varying rate, but in some instances tended to undergo spontaneous degeneration and fibrotic changes. The tumor fails in its completion of the life cycle because in most cases death of the patient occurs before the cycle is completed.

Spontaneous regression of various types of malignant tumors has been reported but a review of the literature fails to reveal an authenticated case of spontaneous regression of bronchiogenic carcinoma. Most of the reports in the literature describe regressions of metastatic carcinomas of genital origin.[2-6]

Certain theoretical factors influencing spontaneous regression of neoplasms have been expressed by Rubens-Duval.[2] He considered autoimmunization and febrile episodes as the most important factors. High body temperature has long been considered an important factor in the regression of cancer. Patients have shown regression of carcinoma following attacks of erysipelas, smallpox, pneumonia, malaria and acute tuberculosis. Coley's serum was first employed because of this observation.

Unfortunately, practical application of hyperthermia or similar measures has not been successful in the treatment of malignant tumors.

The following case report of the spontaneous regression of an authenticated lung cancer is presented.

CASE REPORT

A 59 year old white man was admitted to The George Washington University Hospital on May 19, 1947. The patient had been in good health until September, 1946, when he first noted an increase in a chronic cough which he had had for years. In addition, he

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gave a history of malaise and increasing dyspnea of two months' duration and an eight-pound weight loss over a period of six months.

The past history revealed that the patient suffered from chronic bronchitis of about twenty years' duration. He had smoked from two to three packages of cigarettes daily for many years. He gave a history of liberal alcoholic intake for about twenty-five years.

Physical examination revealed decreased breath sounds over both lung fields, particularly marked in the anterior right chest. No rales were heard. A left direct indirect hernia was present.

Roentgenograms of the chest revealed an opacity in the right lung field at the level of the third and fourth intercostal spaces anteriorly (Fig. 1).

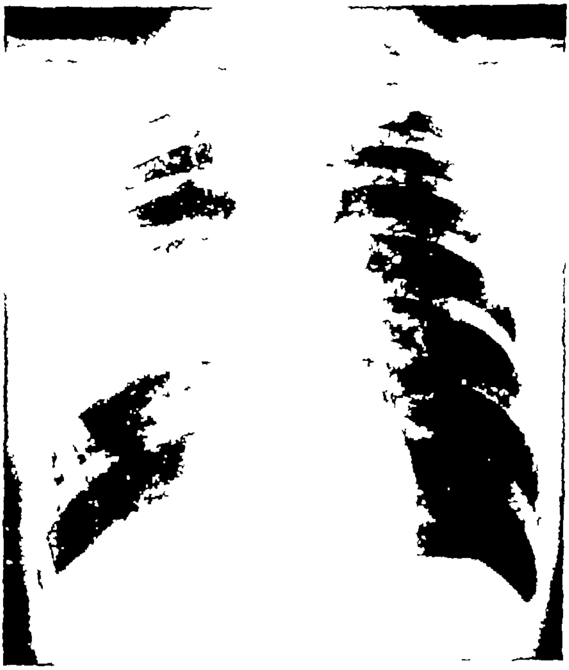

Fig. 1.—Roentgenogram of the chest made July 1, 1947, showing a lesion in the right lung.

Laboratory data demonstrated a slight leukocytosis and a moderate anemia. Further analyses were negative.

Examination with the bronchoscope failed to reveal abnormal tissue for biopsy examinations. A Papanicolaou stain of the bronchial secretions was not done.

The patient left the hospital but was readmitted on July 16, 1947. Appearance of the lesion on chest roentgenograms had not changed during this eight-week period. However, there was temperature elevation to 38.5° C. Forty-eight hours later, the temperature was normal.

On July 20, a right thoracotomy was performed which revealed a carcinoma of the lung with involvement of the right hilum and invasion of the mediastinum at the level of the inferior pulmonary artery.

A biopsy of the mass was taken and since the lesion appeared inoperable, the chest was closed. Microscopic examination of the tissue revealed an epidermoid carcinoma (Fig. 2).

Mitotic figures were present in all microscopic fields and there could be no question about the malignancy of the lesion.

The postoperative course was uneventful The temperature remained elevated from 38 to 38 5° C for the first three postoperative days and then returned to normal The patient received 300 000 units of penicillin daily for five days He was discharged on the ninth postoperative day

During the postoperative period roentgenograms of the chest revealed progressive clearing of the pulmonary lesion in the right lung This became particularly apparent about six months after the exploratory thoracotomy His general condition remained good

The incredible behavior of the pulmonary lesion naturally aroused suspicion that there had been a mistake made in the histologic diagnosis and perhaps a mislabled specimen accounted for an erroneous diagnosis

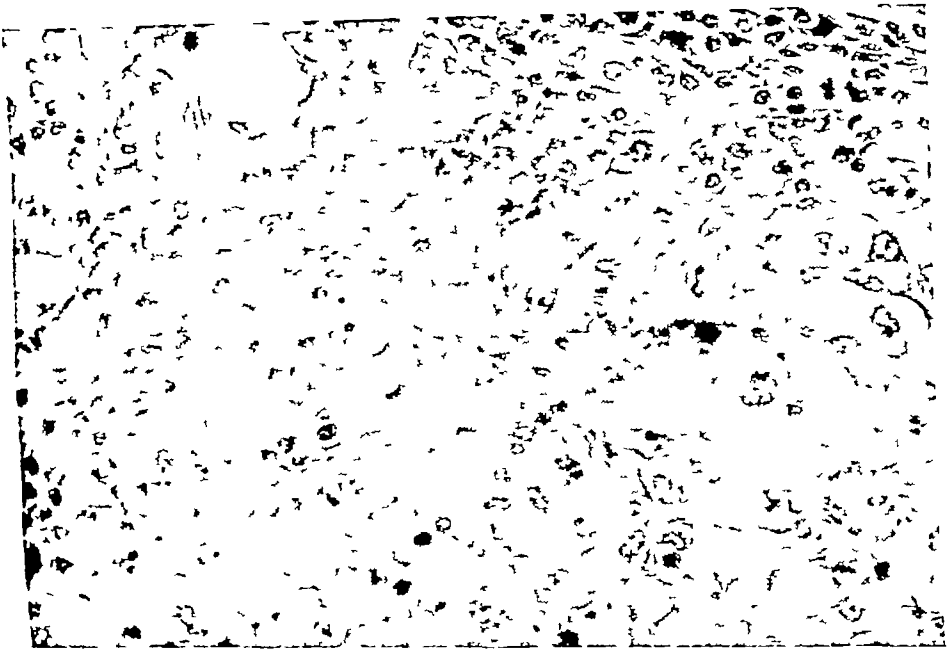

Fig 2—Photomicrograph of section of lung biopsy

Accordingly new sections were made which again revealed epidermoid carcinoma and a careful check on the operative schedule for one week before and one week after the exploratory thoracotomy had been performed established that it was impossible for the specimen to have been misplaced since no other case of bronchiogenic carcinoma had been operated upon during that period Moreover subsequent developments notably bone metastases appeared to establish that the original lesion was malignant

The patient was readmitted to the hospital on May 19 1952 exactly five years after the original admission A careful re evaluation of his entire life history was undertaken in an effort to obtain any pertinent facts which might have influenced the behavior of the lung cancer Nothing of significance could be found except that for four or five years he had been employed as a linotype operator with exposure to noxious fumes This ultimately led him to change his occupation Following the operation in 1947 he took two halibut liver oil capsules daily for a considerable period of time four vegetable compound tablets daily an occasional barbiturate for sleep and vitamin B_1 tablets

The vegetable compound tablets were analyzed and were found to contain asparagus parsley watercress and broccoli

COMMENT

No explanation has been found for the regression of this lung cancer The *postoperative temperature* elevations were not high and cannot be regarded as significant Drugs used by the patient are not considered important and, as far as it is known, have no carcinolytic properties

This case represents the only known instance of spontaneous regression of a bronchiogenic carcinoma Despite evidence of metastasis to the skull, the patient remains in good health more than five years after the original diagnosis of bronchiogenic carcinoma

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Although most writers seem to support the multicentric theory of origin for these tumors Herbut,[4] in 1944 suggested that the lesion described as alveolar-cell tumor had a primary focus and that intrapulmonic metastasis from this focus could account for the gross pattern of these tumors. In 1949, Smith Knudtson and Watson reported that they had been able to trace extension of neoplastic cells along the perivascular lymphatics to distant nodules of tumor. They also suggested that the multiple nodules of tumor could represent intrapulmonic metastasis from a primary focus rather than nodules with a multicentric origin.

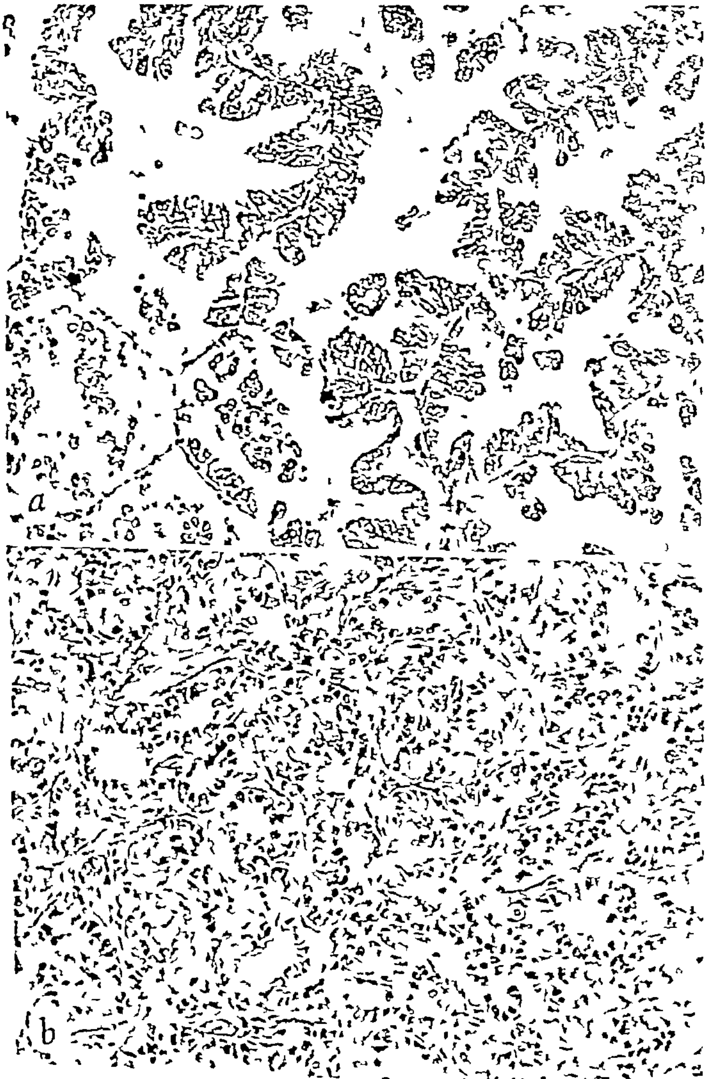

Fig 1 — Alveolar-cell tumor of lung. *a* Typical histologic appearance showing alveoli lined by tumor cells. *b* Section from a different portion of same specimen. Note loss of alveolar pattern.

THE FATE OF PATIENTS WITH ALVEOLAR CELL TUMOR OF THE LUNGS

Thomas W. Mears, M.D.,* John W. Kirklin, M.D.,** and
Lewis B. Woolner, M.D.,*** Rochester, Minn.

Alveolar cell tumor has remained an unsolved problem since the first description of this interesting pathologic lesion by Malassez[1] in 1876. The purpose of this paper is to review the fate of patients whom we have treated at the Mayo Clinic for alveolar cell tumor. At the clinic we first treated a patient having this condition by surgical excision in 1943. Since that time we have treated twelve additional patients surgically. Reports of seven of our thirteen cases have been published previously.[2, 3]

PATHOLOGIC ASPECTS

It is not our purpose to discuss in detail the pathologic characteristics of alveolar-cell tumor. We feel, however, that we must describe the lesion we identify by the term "alveolar-cell tumor of the lung." In all our cases we have carried out careful gross and microscopic re-examination of tissue removed at the time of operation. In all cases the lesion is thought to be primary in the lung. We have excluded any case in which primary adenocarcinoma occurred in any other part of the patient's body.

Alveolar cell tumor involves varying amounts of the lung and on gross examination firm nodules are found which range in size from that of a millet seed to complete involvement of a lobe. Cut sections of these nodules appear similar to the gray hepatization stage of pneumonia. Mucoid material often can be expressed and may be abundant. The histologic pattern of this tumor also is variable. The microscopic sections will show the alveolar septa to be lined by nonciliated columnar cells which show papillary projections into the alveolar spaces. The cytoplasm of the cells is either clear or stained pink. Some cells contain mucus which frequently is secreted into the alveolar space. In the simplest form the cells are remarkable for their monotonous regularity of form, arrangement and staining qualities (Fig. 1, *a*). Histologically, however, considerable variation may be observed on studying multiple sections of a given lesion. Thus in some cases the typical alveolar pattern with relatively benign appearing cells was present in large portions but careful search revealed small foci of anaplastic cells within the tumor in which the pulmonary architecture was no longer preserved (Fig. 1, *b*).

The literature on the pathology of alveolar-cell tumor is abundant but still opinions differ as to whether the tumor originates from epithelial or mesenchymal elements. In fact, there is no agreement that the tumor has a multicentric origin

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**Section of Surgery.

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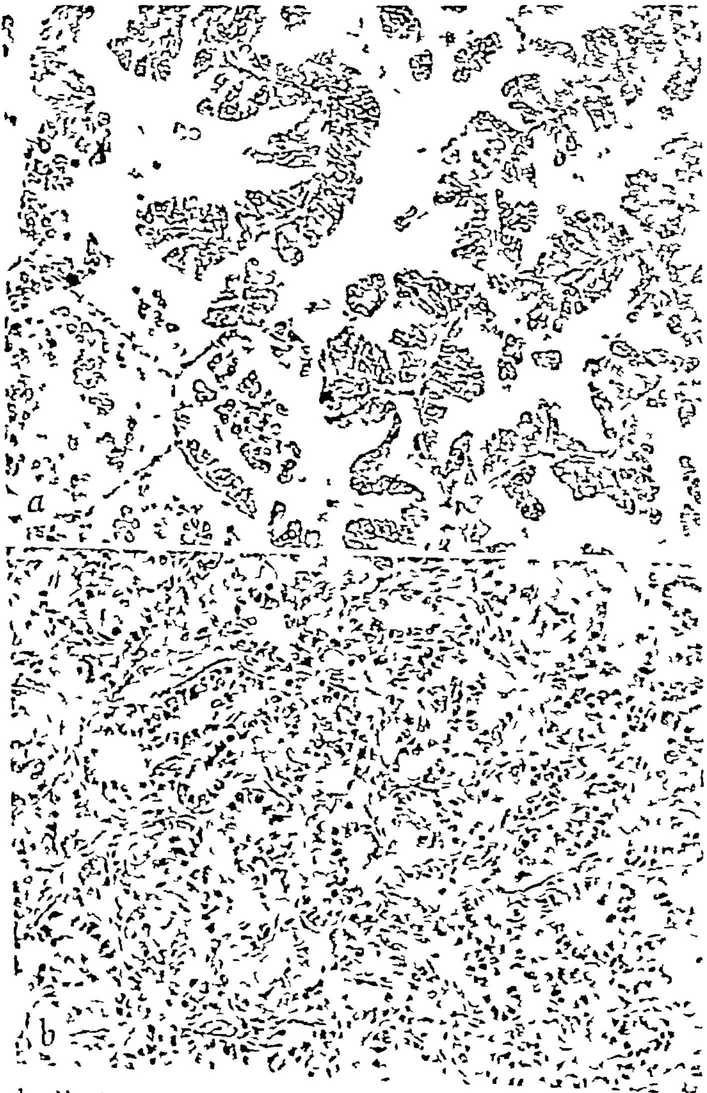

Fig 1.—Alveolar-cell tumor of lung a Typical histologic appearance showing alveoli lined by tumor cells b Section from a different portion of same specimen. Note loss of alveolar pattern.

Of our thirteen patients, ten were women and three were men. The average was 51.8 years, and their ages ranged from 30 to 66 years.

SYMPTOMS

Three patients did not have any symptoms referable to the thorax on primary examination. Instead the tumor was found on roentgenologic examination of the thorax carried out as part of the general examination. The average duration of symptoms in the other ten patients was eleven and one-half months, with a range of one and one-half to twenty-four months. Cough was the commonest symptom and was described by some patients as persistent and by others as intermittent. Varying amounts of sputum were raised. In most instances, however, coughing produced a frothy clear sputum as the disease progressed. Another common symptom was dyspnea, which was usually described as exertional in nature. In the case of one patient, who complained of exertional dyspnea, nocturnal dyspnea also gradually developed as the disease progressed. Fever, which varied from bouts of chills and fever to a minimal elevation of temperature in the afternoon, was a symptom described by six patients. Pain in the thorax and hemoptysis were complaints in five cases. Only three patients mentioned loss of weight.

PHYSICAL AND ROENTGENOLOGIC EXAMINATIONS

The physical examination was of little clinical significance except for the fact that depressed breath sounds were heard over the affected area.

The roentgenologic examination of the thorax may show a small, poorly defined region of consolidation in the lungs which appears to be pneumonitis. As the disease progresses, other portions of one or both lungs may become involved. In the advanced stages both lungs are involved with multiple foci which frequently become confluent and give the appearance of a mass or of a consolidated lobe.

In each of our cases the lesion was demonstrated on roentgenologic examination of the thorax. Our studies agreed with those of other authors on this subject, in that characteristic findings which could be considered diagnostic were not found.

BRONCHOSCOPIC AND CYTOLOGIC ASPECTS

Bronchoscopic examination was done in each case. The gross findings at the time of bronchoscopy were significant in eight cases. A frothy mucoid material was described coming from the involved segments of the bronchial tree in five cases and some deformity of a bronchus was noted in three cases. Biopsy was done at the time of bronchoscopy in four cases. In one of these positive evidence for carcinoma was found, and the pathologist suggested the possibility of an alveolar cell tumor.

Preoperative cytologic examination was done in eleven cases. Malignant cells were found in either or both the sputum and bronchial washings in seven (63.6 per cent) cases.

The sputum should be examined postoperatively for malignant cells in order to ascertain whether all the involved lung has been removed. At times groups of malignant cells will be found in the sputum after operation indicating that small foci of neoplastic tissue remained which were of insufficient size to be detected roentgenologically or grossly at operation

TREATMENT

Neubuerger and Geever[6] reported that 50 per cent of their patients had metastasis and in half of these distant metastasis was present Only one of our patients showed spread to the hilar lymph nodes at the time of operation Although necropsy was not done this patient also showed evidence of cerebral involvement before death five and one-half months later Infrequently, the disease apparently remains localized to one lobe for a period of months or years

The extent of resection should be as conservative as possible and yet all neoplastic tissue should be adequately removed. Lobectomy was the operation of choice in ten cases and pneumonectomy was carried out three times It is of interest to note the preponderance of operative procedures on the left lung The lower lobe was resected in eight cases and the upper lobe in two The right upper lobe was removed in two cases and all three pneumonectomies were on the right side

Two patients had second operations for this disease One had recurrence of symptoms plus roentgenologic evidence of recurrent tumor in the lower lobe of the left lung This lobe was resected completing the pneumonectomy Subjectively this patient improved but the sputum remained positive for malignant cells postoperatively At the time of this writing she has further evidence of a tumor in the right lung and her condition is becoming worse steadily

The other patient had the right upper lobe removed at a second-stage procedure two and one half months after removal of the left lower lobe She died in the postoperative period of pulmonary edema Necropsy did not show evidence of residual tumor in the remaining portions of the lungs

Roentgen therapy was used in addition to surgical excision of the lesion in four cases but the course of the disease evidently was not altered in any of these people All are now dead of their disease

Other methods of therapy have been described in the literature including the use of nitrogen mustard[4, 7] and of Teropterin.[4] In each case apparent beneficial effects were not obtained

Results of treatment in these cases have been very disappointing Fifteen operations were carried out on the thirteen patients and two deaths occurred in the immediate postoperative period Only four of our thirteen patients are living at the time of this study and two of these have evidence of recurrent tumors Of the two patients who are living and who do not show evidence of recurrence one has survived operation four years and the other one year Although as yet none of our patients has survived five years cases of a few five year survivors are reported in the literature Five of the nine patients who died showed evidence of recurrent disease Two patients died in the immediate postoperative period and necropsy did not show evidence of residual tumor in either case. Two patients who survived the operation died of other causes. One had Hodgkin's disease and the other one died suddenly of unrelated disease. Necropsy was not done on the latter patient but when seen at the clinic about six months prior to death, recurrence of the tumor was not evident.

Even though this method of treatment is only palliative to most patients, the few who have been treated in this manner and who have survived this dreadful disease still encourage us a bit. We are of the opinion that the patient should not be denied operation even though too often the disease will recur in a previously normal appearing lung, and the patient will eventually die as a result of asphyxia, metastasis, or pneumonitis.

SUMMARY

We have reviewed our experiences with the treatment of ten women and three men who had alveolar-cell tumor of the lungs. The average age was 51.5 years.

Three patients in our group did not have symptoms referable to the thorax when they were first examined. The average duration of symptoms in the remaining ten patients was eleven and one-half months. The commonest symptoms were cough, dyspnea, fever, pain in the thorax, and hemoptysis. The lesions were demonstrated on roentgenologic examination of the thorax but their appearance was not diagnostic.

The usual significant finding at bronchoscopy was a frothy mucoid sputum coming from the involved segments of the lung. Either the bronchial washings or the sputum or both were positive for malignant cells in 63.6 per cent of the cases in which cytologic examination was done.

Although the results of treatment are disappointing, the only method of treatment of even palliative value at the time of this study is conservative surgical excision of the affected portions of the lung.

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THE USE OF DIRECT PRESSURE MEASUREMENT AT THE OPERATING TABLE TO EVALUATE THE ACUTE RESULTS OF CORRECTIVE CARDIAC SURGERY

HENRY A. ZIMMERMAN, M.D.,[*] AND EARLE B. KAY, M.D.[**]
CLEVELAND, OHIO

THE ability to differentiate and classify congenital cardiac anomalies into separate entities has progressed rapidly with the advent of cardiac catheterization and angiocardiography. This increase in understanding of such anomalies has reflected itself in the perfection of techniques for surgical correction.

However, a group of anomalies remains where the diagnosis can only be suspected and verification must await surgical exploration. During cardiac catheterization at times the catheter cannot be introduced into the pulmonary artery or into the right ventricle. Hence differentiation between pulmonic stenosis, atrial, and ventricular septal defects and the combination of these conditions may be impossible. During the past two years, the use of direct pressure measurements at the operating table has frequently allowed this differential diagnosis to be made.

Also in cases of pulmonic or infundibular stenosis the exact portion of the stenosis can be determined by obtaining the pressure differential proximal and distal to the point of obstruction. This information is of the utmost value to the surgeon in determining the site of the myocardotomy and the technique to be employed.

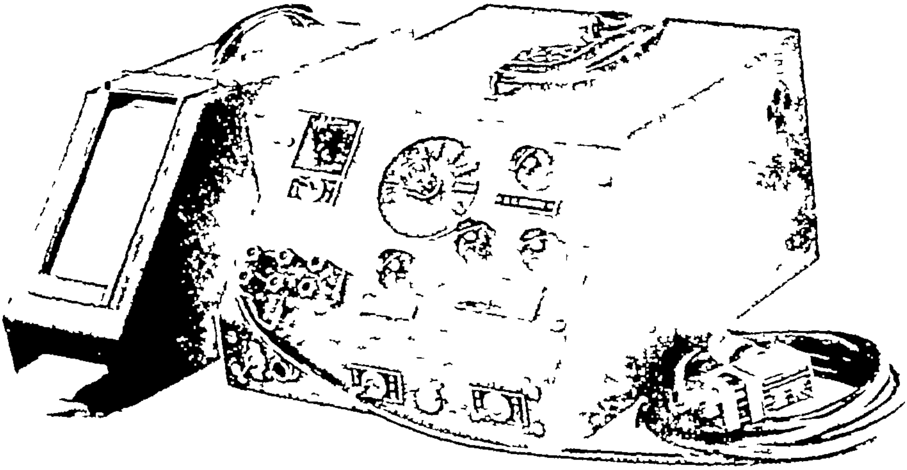

FIG. 1.—The Ihotron single channel direct writer and the Ihotron strain gauge analyzer with a Statham pressure transducer. Notice the portability of this equipment.

From the Cardiovascular Laboratory, St. Vincent's Charity Hospital.
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[**] Chief Thoracic Surgeon.

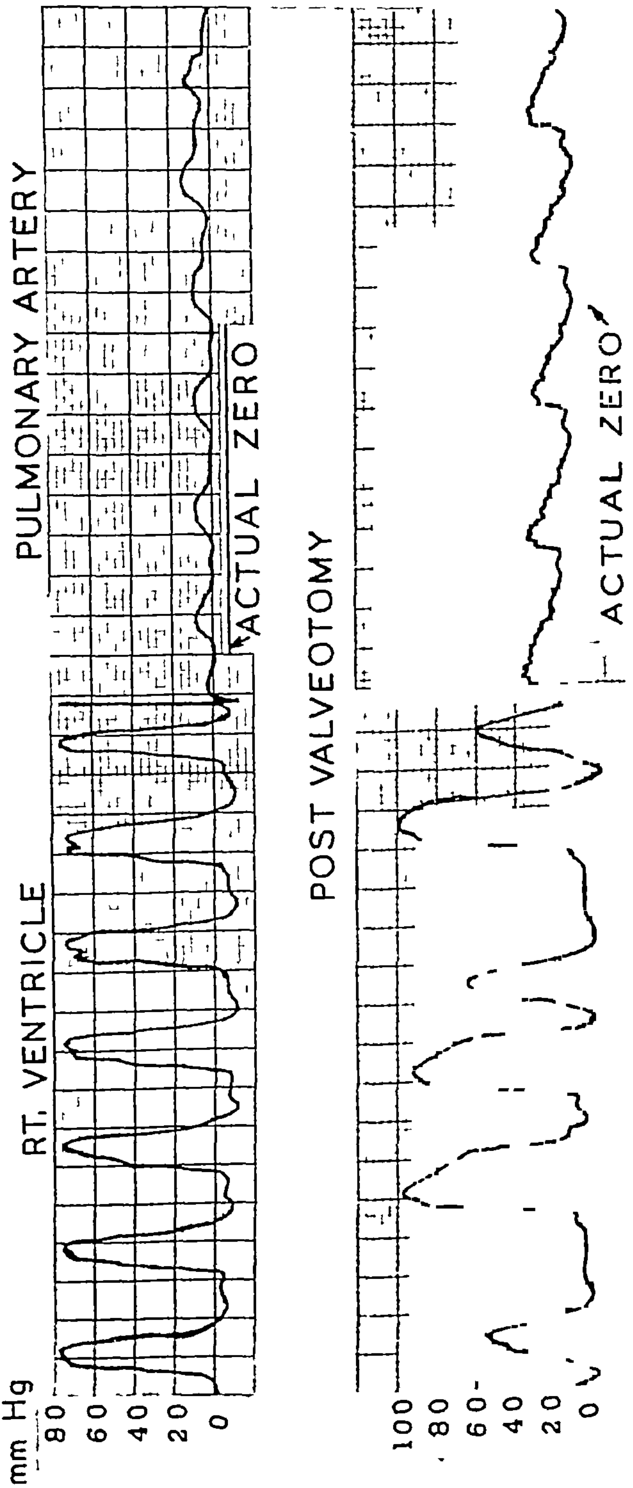

Fig. [illegible].—The pre- and postvalvulotomy pressures on a 28 year old white man with a tetralogy of Fallot. Note: Following valvulotomy the pulmonary artery pressure is doubled and the pressure curve resembles more that obtained in a normal pulmonary artery as compared with the damped curve taken before valvulotomy.

The apparatus that is used consists of a Statham pressure transmitter filled with aqueous Zephiran chloride 1 per cent and the hub of the gauge filled with heparin 10 mg per cubic centimeter The gauge is immersed in a 1 per cent aqueous Zephiran chloride 1 per cent solution, and allowed to soak from twenty to thirty minutes the gauge and lead-in wires are covered with two layers of sterile stockinette through which the sterile hub protrudes and this is in turn connected to a 22 or 23 gauge needle or a Beck-Dickerson arterial needle which is placed in the desired area to record pressures Pressures are then recorded by means of strain gauge amplifiers of the Photron or Sanborn type these feed the signal into a single or double channel Photron or Sanborn direct writing recorder

By means of an attenuator setting on the strain analyzer, the sensitivity of the gauge can be varied to record any pressure 0 mm Hg up to 500 mm of Hg The pressure curve can be adjusted for maximal swing

The equipment is quite mobile and especially the Photron instrument equipment which consists of a small pen motor in a separate case and a strain amplifier with the gauge connected in another case (Fig 1) This can be carried from operating room to operating room or from hospital to hospital in a small carrying case

It is also possible by this method to determine immediately the effectiveness of the surgical procedure in cases of pulmonic or infundibular stenosis If the pressure has not been sufficiently reduced in the right ventricle and elevated in the pulmonary artery this information can be immediately obtained and the condition remedied It is interesting to note how frequently it is necessary to re enter the heart and to improve the size of the stenotic area before equalization of pressures is obtained that would not have been accomplished without the benefit of direct pressure measurements taken at the time of surgery

This procedure can be done with a minimal amount of time expenditure and yet gives the operator a very objective method of evaluating his immediate operating results in the form of hemodynamic changes, which should, for all intents and purposes, predict his long-range results

Fig 2 illustrates the case concerning a 28-year-old man with a tetralogy of Fallot who had a pulmonary valvulotomy performed Note the graduation in the return of the pulmonary pressure curve to normal following corrective surgery as the opening in the stenotic valve increased in size

CONCLUSIONS

1 A simple method for taking direct pressures at the time of cardiac surgery is described

2 This procedure aids in the differential diagnosis of congenital heart lesions

3 It determines the site of stenosis in patients with pulmonary or infundibular stenosis and whether the stenosis is sufficiently opened following corrective surgery

THE AMERICAN ASSOCIATION FOR THORACIC SURGERY

Thirty-Fourth Annual Meeting
May 3, 4, and 5, 1954, Sheraton-Mt Royal Hotel
Montreal Canada

Program

Monday Morning, May 3 1954

8 30 A M Business Meeting

9 00 A M Scientific Session—Regular Program

1 **Lipid Deposition in Pulmonary Tissue**
William R Waddell (by invitation), Ronald C Suffen (by invitation) and Lawrence L Whytehead, (Travelling Fellow of the Association (by invitation) Boston Mass

2 **Absence and Hypoplasia of a Pulmonary Artery Unassociated With Congenital Heart Disease**
Herbert C Maier New York N Y

3 **Surgical Reconstruction of the Superior Vena Cava**
J Gordon Scannell and Robert S Shaw (by invitation) Boston Ma

4 **Stilbamidine as an Adjunct to the Surgical Treatment of Pulmonary Blastomycosis**
Page W Acree (by invitation), New Orleans La

5 **The Conservative and Surgical Management of Benign Strictures of the Esophagus**
Paul H Holinger, Kenneth C Johnston (by invitation) Willis J Potts and Fernando daCunha (by invitation), Chicago, Ill

6 **A Method of Preventing Peptic Esophagitis Following Esophagogastrostomy Experimental and Clinical Study**
David H Watkins (by invitation), Arthur Prevedel (by invitation) and Fred R Harper, Denver, Colo

Monday Afternoon May 3, 1954

2 00 P M Scientific Session—Regular Program

7 ***Opportunities for Research in Thoracic Surgery* With the Use of Tissue Culture Methods**
C M Pomerat (by invitation) Galveston, Texas

8 ***The Results of Treatment in Carcinoma of the Lung***
David P Boyd, Howard B Kirtland (by invitation) Magnus I Smedal (by invitation), and John G Trump (by invitation), Boston Mass

9 ***A Clinical Survey of Adenomas of the Trachea and* Bronchus in a General Hospital**
Lamar Soutter Boston Mass

10 ***Palliation of Esophageal Obstruction Due to* Carcinoma With a Permanent Intra Luminal Tube**
S A Mackler and Roland Mayer (by invitation), Chicago, Ill

11 ***Studies on Cardiac Arrest* The Relationship of Hypercapnia to Ventricula Fibrillation**
Will C Sealy W Glenn Young (by invitation) and Jerome S Harri (by invitation) *Durham N C*

12 **The Physiology of Hypothermia and Its Application to Cardiac Surgery**
W G Bigelow (by invitation) Toronto Ont

Tuesday Morning May 4 1954

8 30 A.M SCIENTIFIC SESSION—Thoracic Surgical Forum

13 **Use of the Endotracheal Tube in Pulmonary Edema**

Watts R Webb (by invitation) and Guy D Campbell (by invitation) Sanatorium Miss

14 **A Satisfactory Shunting Technique for Surgery of the Aortic and Pulmonary Valves and Proximal Great Vessels.**

Frederick S Cross (by invitation) and Earle B Kay Cleveland Ohio

15 **The Closure of Interventricular Septal Defects in Dogs During Open Cardiotomy With the Maintenance of the Cardiorespiratory Functions by a Pump Oxygenator**

Bernard J Miller (by invitation) Hans C Engell (by invitation) Anthony R Dobell (by invitation) and John H. Gibbon Jr Philadelphia Pa

16 **Studies of the Venous Collateral Circulation of the Lung**

Alfred Hurwitz Averill A Liebow (by invitation) Paul Kunkel (by invitation) Massimo Calabresi (by invitation) and Ronald W Cooke (by invitation) New Haven Conn

17 **The Physiological Basis for Utilization of Esophagocardiomyotomy in the Treatment of Achalasia—An Experimental Study**

Paul Nemir Jr (by invitation) and H R Hawthorne (by invitation) Sponsored by Julian Johnson Philadelphia Pa

18 **The Effect of Intrapericardial and Intracardiac Procaine Upon the Circulation in Man.**

E M Papper Hugh Fitzpatrick (by invitation) Enzo Krahl (by invitation) J F McAllister (by invitation) and George H Humphreys II New York, N Y

19 **Intracardiac Surgery With the Aid of Artificial Operative Tunnels**

William K Swann (by invitation) Jacob T Bradsher Jr (by invitation) and Jorge Rodriguez Arroyo (by invitation) Knoxville Tenn

20 **Cardioangiography**

Philip W Smith (by invitation) Hugh Craig (by invitation) and Karl P Klassen Columbus Ohio

21 **Creation of Autogenous Vessels.**

Newton Chun (by invitation) Richard Forney (by invitation) and Egbert H Fell (by invitation) Chicago Ill

22 **Experimental Esophagogastrectomy Evaluation of Gastric Drainage Procedures Performed in Association With Esophagogastrectomy**

Harold W Neuman (by *invitation*) and F Henry Ellis (by invitation) Sponsored by Herbert W Schmidt Rochester Minn

23 **Experimental Pedunculated Flaps Used for Cardiac Abnormalities in Dogs**

Arnold F Botwin (by invitation) Kansas City Kan

24 **Synchronous Combined Abdomino-Right Thoracic Approach for Carcinoma of the Middle Third of the Esophagus**

Hawley H. Seiler (by invitation) Tampa Fla

25 **Differential Behavior of Arterial Homografts Implanted in the Thoracic and Abdominal Aorta.**

Edmund A Kanar (by invitation) Lloyd M Nyhus (by invitation) Horace G Moore Jr (by invitation) Ralph K. Zech (by invitation) and Henry N Harkins (by invitation) Sponsored by K Alvin Merendino Seattle Wash

26 **A Method of Supplementing the Coronary Circulation by a Jejunal Pedicle Graft.**

James A Key (by invitation) Frederick G Kergin Yves Martineau (by invitation) and R G Leckey (by invitation) Toronto Ont

27 **Controlled Cross Circulation for Intracardiac Surgery**
Herbert Warden (by invitation), Morley Cohen (by invitation), Raymond C Read (by invitation), and C Walton Lillehei (by invitation), Sponsored by Richard L Varco, Minneapolis, Minn

Tuesday Afternoon May 4, 1954

2 00 P M EXECUTIVE SESSION—(Limited to active and senior members)

3 00 P M SCIENTIFIC SESSION—Regular Program

ADDRESS OF THE PRESIDENT—Emile Holman, San Francisco, Calif

28 **The Surgery of Infundibular Pulmonic Stenosis With Intact Ventricular Septum (A Type of "Pure" Pulmonic Stenosis)**
Robert P Glover, Hugo Gontigo (by invitation), Thomas C McAuliffe (by invitation), Thomas J E O'Neill, and Robert E Wells (by invitation), Philadelphia, Pa

29 **Pulmonic Valvular Stenosis Technic of Open Valvuloplasty and Results**
Henry Swan, Henry C Cleveland (by invitation), Helmut Mueller (by invitation), and S Gilbert Blount (by invitation), Denver, Colo

30 **Experiences in the Surgical Treatment of Aortic Stenosis**
William H Muller, Jr, Albert A Kattus (by invitation), T Francis Dammann, Jr (by invitation), and Rodney T Smith (by invitation), Los Angeles, Calif

6 30 P M COCKTAILS AND DINNER—Sheraton Mt Royal Hotel

ADDRESS BY GUEST OF HONOR—Dr F Cyril James, principal and vice-chancellor, McGill University, Montreal

Attendance limited to members of the Association and their wives, invited speakers and their wives

Dinner dress

Wednesday Morning, May 5, 1954

9 00 A M SCIENTIFIC SESSION—Regular Program

31 **The Surgical Correction of Mitral Insufficiency by Valvular Suturing**
Charles P Bailey, W L Jamison (by invitation), H T Nichols (by invitation), and A Bakst (by invitation), *Philadelphia, Pa*

32 **The Surgical Correction of Mitral Insufficiency**
Dwight E Harken, Harrison Black, Laurence B Ellis (by invitation), and Lewis Dexter (by invitation), Boston, Mass

33 **Four Years' Clinical Experience With Internal Mammary Artery Implantation in the Treatment of Human Coronary Artery Insufficiency Including Additional Experimental Studies**
Arthur Vineberg, D D Munro (by invitation), Herman Cohen (by invitation), and William Buller (by invitation), Montreal, Canada

34 **Anatomic Physiologic and Surgical Considerations in Closure of Atrial Septal Defects in Man.**
John W Kirklin, Earl H Wood (by invitation), Jesse E Edwards (by invitation), and Howard B Burchell (by invitation), Rochester, Minn

35 **Aortic Arch Resection and Grafting for Aneurysm Employing an External Shunt**
Allan Stranahan, Ralph D Alley (by invitation), William H Sewell (by invitation) and Harvey W Kausel (by invitation), Albany, N Y

36 ***Resection of the Thoracic Aorta With Replacement by Homograft for* Aneurysms and Constrictive Lesions**
Denton A Cooley and Michael E DeBakey, Houston, Texas

Wednesday Afternoon, May 5, 1954

2 00 P M SCIENTIFIC SESSION—Regular Program

37 **The Viability of Tubercle Bacilli in Healed Tuberculous Lesions Following Long Term Chemotherapy**

Gladys L Hobby (by invitation), Oscar Auerbach, Tulita F Lenert (by invitation), Maurice J Small (by invitation), and John V Comer (by invitation), East Orange, N J

38 **Resection Surgery in Tuberculosis Complications and After-History**

Richmond Douglass, James M. Judd (by invitation) E B Bosworth (by invitation), and K. H Chang (by invitation), Ithaca, N Y

39 **The Coordination of Surgery and Combined Chemotherapy in the Treatment of Pulmonary Tuberculosis**

Alfred M Decker (by invitation), James W Raleigh (by invitation), and Edward S Welles, Sunmount, N Y

40 **The Role of Pulmonary Insufficiency in Mortality and Invalidism Following Surgery for Pulmonary Tuberculosis**

Edward A Gaensler, David W Cugell (by invitation), Jean M Verstraeten (by invitation), Sylvia S Smith (by invitation), and John W Strieder, Boston, Mass

41 **Experiences With Enlarging the Indications for Tracheal and Bronchial Grafts**

Osler A Abbott, Wm E VanFleit (by invitation), and Albert Roberto (by invitation), Emory University, Ga

42 **Bronchial Anastomosis and Bronchoplastic Procedures in the Interest of Preservation of Lung Tissue**

Donald L Paulson and Robert R Shaw, Dallas, Texas

Certain Actions Taken at Council Meeting, March 30, 1953

It was decided by the Council that the following actions should be published in the JOURNAL before the 1954 meeting of the Association

"The Council reaffirms the attendance rule (By Laws, Article IV, Sect 7) which states that 'The Council shall recommend that any Active or Associate member who has been absent without sufficient excuse from *three* consecutive annual meetings shall have his membership terminated '

"The Council directs that attention to this rule be publicized during the coming year by publication in the JOURNAL announcement at the Executive Session and circularizing the membership with a letter quoting the Council action Mandatory adherence to this rule will be enforced beginning with the 1954 meeting of the Council "

Resolutions Concerning the American Board of Anesthesiology

The following resolution was passed by the Council and ordered published in the JOURNAL

"Whereas It has been brought to our attention that the American Board of Anesthesiology has declared and has exercised its right to withdraw its certificate of qualification from anyone who is not a member of the American Society of Anesthesiologists, and

'Whereas This custom has worked great economic hardship on certain well qualified anesthesiologists to whom the only objection raised was the method of receiving their compensation and

'Whereas In the opinion of the Council of The American Association for Thoracic Surgery this arbitrary custom is contrary to the best traditions of the practice of medicine and surgery therefore be it

"Resolved, That the Council of The American Association for Thoracic Surgery express its disapproval of the action of any specialty board in attempting to exert economic pressure on anyone who has demonstrated his proficiency in the field by holding a certificate of the Board in question."

THE AMERICAN BOARD OF THORACIC SURGERY HAS REQUESTED THAT THE FOLLOWING RESOLUTION PASSED BY IT BE PUBLISHED IN THE JOURNAL OF THORACIC SURGERY

"Certain trends, on the part of specialty boards and other medical organizations to *prescribe the methods of compensation for medical services have created the necessity for the* Board of Thoracic Surgery to define its objectives.

"The Board of Thoracic Surgery has no interest in whether its diplomates are compensated on a fee for case basis, a salary, or both.

"The purpose of the Board of Thoracic Surgery is to establish adequate standards of training in thoracic surgery and to conduct examinations to determine the qualifications of the candidates."

The 1955 Meeting of the Association for Thoracic Surgery Will Be Held April 24, 25, and 26 (Sunday, Monday and Tuesday) in Atlantic City, New Jersey. The Headquarters Will Be at The Chalfonte Haddon Hall.

The Journal of
Thoracic Surgery

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Original Communications

PROTECTION OF THE HEART BY ARTERIALIZATION OF THE CORONARY SINUS

I. Coronary Collateral Flow in Normal Dogs and in Dogs Having Had Previous Nondescript Cardiac Surgery

Alvin A. Bakst, M.D., Jaime Costas-Durieux, M.D., Harry Goldberg, M.D.,
and Charles P. Bailey, M.D.
Philadelphia, Pa.

Surgical therapy for the treatment of coronary artery disease has been experimented with for over fifty years. Pratt[1] first suggested the possibility of maintaining the nutrition of the heart by reversing the flow of blood in the cardiac veins in 1898. He forced defibrinated arterial blood into the coronary sinus of freshly extirpated cats' hearts, and noted that both ventricles continued to contract in a regular and coordinated manner at intermittent periods for one and one half hours.

Roberts and associates[2] created an arteriovenous anastomosis between a systemic artery and the coronary sinus in dogs by means of a connecting glass cannula. The cardiac veins became distended, pulsatile, and arterial in color. After it was felt that reversal of flow had occurred, coronary arterial ligation was performed. The hearts continued to beat regularly and forcefully for as long as twenty-six hours. Chicago blue dye injected into the coronary sinus resulted in complete delineation of the capillaries. The authors suggested that an ischemic myocardium may be revascularized by anastomosis of a large artery to the coronary sinus.

Beck and co-workers[3, 4] devised a procedure for the revascularization of the human heart in occlusive disease of the coronary arteries. The technique utilized the placement of a free vein graft between the aorta and the coronary sinus following which the coronary sinus was partially ligated several weeks later. These workers have demonstrated that arterialization of the coronary sinus

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From the Departments of Thoracic Surgery and Physiology and the Brith Sholem Cardio-Pulmonary Laboratory, Hahnemann Medical College and Hospital, and the Bailey Thoracic Clinic.

This work was supported by the Mary Bailey Foundation.

This study was carried out during the tenure (A. A. B.) of a Heart Traineeship sponsored by the National Heart Institute.

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provides for adequate protection to the heart during major coronary artery ligation. Ligation of the left anterior descending coronary artery at its origin in normal dogs results in a 70 per cent mortality. Ligation of this vessel following arterialization of the coronary sinus results in a reduction of the mortality rate of 20 to 30 per cent. In addition, normal dogs surviving ligation of the left anterior descending artery present large myocardial infarcts. In the dogs with aorticocoronary sinus anastomoses surviving anterior descending ligation myocardial infarcts are either small or nonexistent. Hahn and associates[7] were able to prepare three sinus-arterialized dogs which survived ligation of all coronary arteries except for the septal branch of the left coronary artery for a period of five months, at which time they were sacrificed. These workers also noted that the blood flowing in retrograde fashion from the distal cut end of the divided left circumflex coronary artery in such dogs increased as progressive occlusion of the left main coronary artery was performed. India ink injected into the graft was identified in the blood obtained from the retrograde flow of the divided coronary artery.

Smith and co-workers[8] attempted to elucidate the mechanisms of protection afforded by arterialization of the coronary sinus in acute experiments. They demonstrated that elevation of the coronary sinus pressure without arterialization reduced the mortality following circumflex coronary artery ligation from 70 per cent in normal dogs to 40 per cent. Coronary sinus pressure elevation with arterialization of the sinus in these acute experiments further reduced the mortality to zero. They concluded that arterialization of the sinus provided the greatest protection against ventricular fibrillation following coronary artery ligation and that such arterialization was the only practical means of chronically elevating coronary sinus pressure to effective levels.

Eckstein and associates,[9, 10] in a series of acute experiments, stated that a small retrograde flow was present in dogs in which the coronary sinus was arterialized, using a glass cannula for the anastomosis. They noted that the retrograde flow from the distal segment of the occluded circumflex artery apparently increased with augmentation of pressure in the coronary sinus and was related to the diastolic pressure.

In recent years, we have been interested in arterialization of the coronary sinus for the surgical therapy of occlusive coronary artery disease. Bailey and co-workers,[11, 12] by the use of injection techniques, were able to demonstrate that it is anatomically possible for a perfusate introduced into the coronary sinus to reach the capillary bed by flowing in retrograde fashion. However, it remains to be demonstrated that this retrograde perfusion of the myocardial capillary bed actually occurs in the sinus-arterialized heart of the living animal.

We have been able to confirm the observation made by Hahn and Beck in demonstrating a significant protection to the heart against ventricular fibrillation following major coronary artery ligation in dogs having a chronically arterialized coronary sinus.[13] Our recent interest lies in the physiologic explanation of this protection. Accordingly, in a series of experiments, we have attempted to elucidate the following points with respect to chronic arterialization of the coronary sinus in dogs: (1) Whether or not the myocardial capillary bed can actually be perfused in retrograde fashion (2) if retrograde blood flow does occur, whether or not this blood traverses the capillary bed with extraction of oxygen and (3) whether or not there is an increase in the inter-arterial coronary collateral flow. In order to obtain this information we felt that it was necessary to obtain control data first. The following information was therefore secured in the normal dogs (1) Coronary sinus pressure and oxygen content of coronary sinus blood (2) quantitative determination of retrograde blood flow from the circumflex coronary artery following its ligation from a point distal to the ligature and (3) determination of oxygen content and saturation upon simultaneously drawn blood samples from the pulmonary artery, aorta and the distal segment of the transected circumflex coronary artery. Inasmuch as it might be questioned whether the production of pericardial adhesions following any cardiac procedure might alter these findings we felt it essential to repeat these experiments in dogs having previously had nondescript cardiac operations. When possible, dogs were used in which the coronary sinus had been unsuccessfully arterialized with subsequent thrombosis of the graft.

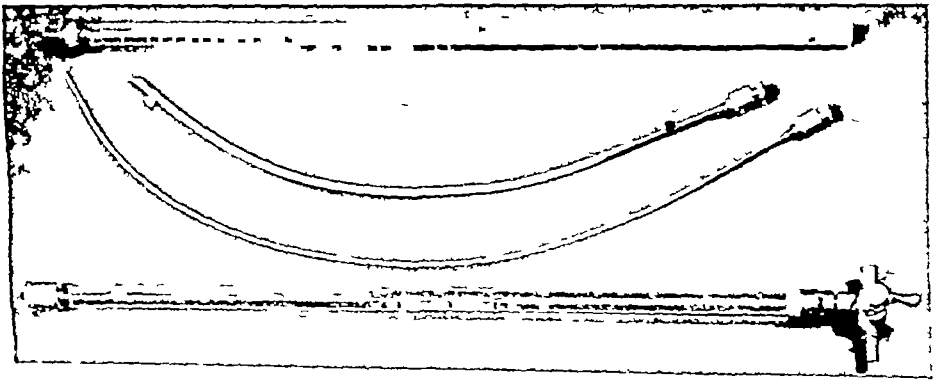

Fig 1.—The needle-tipped polythene catheter (*center bottom*) is inserted into the coronary sinus and attached to the water manometer. This permits the securing of accurate pressure readings. The obliquely cut polythene catheter (*center top*) is used to cannulate the distal segment of the ligated left circumflex artery. The cannula fits snugly within the lumen of the vessel and prevents leakage of blood around it, thus safeguarding accurate retrograde arterial flow studies.

METHODS

Group A consisting of ten mongrel dogs whose weights varied between 11 and 17 kilograms constituted the normal control. They were anesthetized with Halatal* and under artificial respiration the left thorax was opened through the fourth intercostal space. The pericardium was slit and with the aid of a needle tipped polythene catheter the coronary sinus was cannulated. The cannula was connected to a water manometer (Fig 1) and the sinus pressure was obtained (Fig 2). A specimen of coronary sinus blood was drawn. The circumflex branch of the left coronary artery was isolated and ligated at its origin. An incision was made in the artery just distal to the ligature through

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* A preparation of pentobarbital sodium

which the distal segment of the artery was cannulated Simultaneous blood samples were taken from the pulmonary artery, the aorta, and the distal segment of the ligated circumflex artery The minute volume of retrograde blood flow from the cut end of the distal portion of the circumflex artery was secured (Fig 3) The oxygen content of all blood samples was determined Oxygen capacity and saturation were determined in the aortic sample obtained from these normal control animals

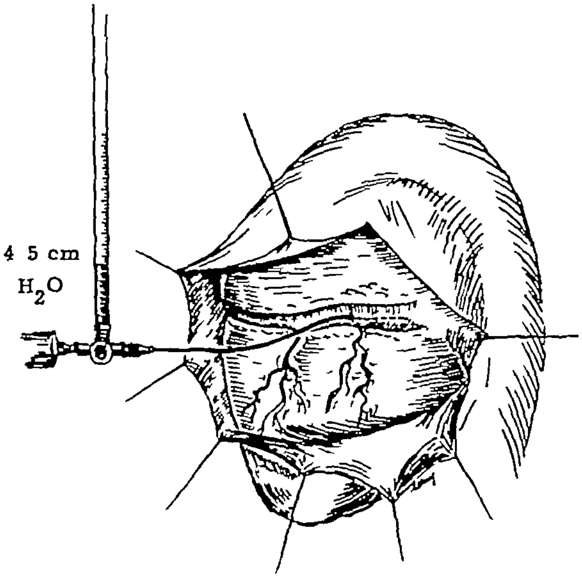

Fig 2

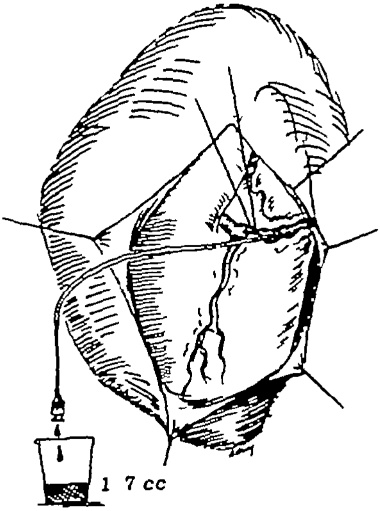

Fig 3

Fig 2.—A needle-tipped polythene catheter is attached to a water manometer and inserted into the coronary sinus The recording of the mean coronary sinus pressure is doubly checked since the fluid level in the manometer is permitted first to fall and then rise to its end point. A blood specimen is then obtained for the determination of oxygen content.

Fig 3.—The circumflex branch of the left coronary artery is dissected to its origin where it is ligated An incision is made in the artery distal to the ligature and a polythene cannula is inserted Retrograde blood flow from this distal cannulated segment of circumflex coronary artery is recorded and blood samples are secured for the determination of oxygen content

Group B consists of ten mongrel dogs of similar weight on which nondescript cardiac surgery had been previously performed In four of these dogs a previous unsuccessful attempt to arterialize the coronary sinus had been made but the grafts were demonstrated to be thrombosed and nonfunctioning The remaining dogs had had the right atrium opened for periods of six to twelve minutes during hypothermia experiments performed one to three months previously In addition in some of these interatrial septal defects had been created and closed In five of the dogs the anterior descending branch of the left coronary artery was ligated at its origin and in the remaining five, the circumflex branch of the left coronary artery was ligated at its origin The distal segment of the ligated vessel was then cannulated

RESULTS

1 *Retrograde Blood Flow From the Distal Segment of the Ligated Circumflex Branch of the Left Coronary Artery*.—

Group A The results in the dogs in this group are shown in Table I. The retrograde bleeding ranged from 0.4 c.c. to 5.0 c.c. with an average of 1.7 c.c. per minute.

Group B The results are shown in Table I. Retrograde bleeding from the distal segment of the ligated circumflex branch of the left coronary artery ranged from 0.5 c.c. to 6.0 c.c., with an average of 1.9 c.c. per minute. Retrograde bleeding from the left anterior descending artery ranged from 1.8 c.c. to 11.0 c.c. per minute with an average of 5.1 c.c. per minute. It should be noted that in two dogs (Table I, Group B, 9, 10) there was an unusually large amount of retrograde bleeding. In both animals a large accessory anterior descending branch was observed to arise from the circumflex artery and to course downward over the left ventricle parallel to the ligated left anterior descending artery. This accessory artery may have accounted for the excessive retrograde bleeding by providing additional intercoronary communications.

TABLE I RETROGRADE BLOOD FLOW FROM THE DISTAL CUT END OF THE LIGATED CIRCUMFLEX BRANCH OF THE LEFT CORONARY ARTERY (CUBIC CENTIMETERS PER MINUTE)

GROUP A	NORMAL DOGS	GROUP B	DOGS WITH PREVIOUS CARDIAC SURGERY
1	2.2	1	1.1
2	1.4	2	1.2
3	4.4	3	1.2
4	0.4	4	6.0
5	0.4	5	0.5
6	0.5	Average	1.9
7	0.6		
8	1.1	*Left Anterior Descending Artery*	
9	1.0		
10	5.0	6	1.4
Average	1.7	7	1.8
		8	1.5
		9	11.0
		10	6.2
		Average	5.1

2 *Oxygen Content of the Retrograde Blood Samples Obtained From the Distal Segment of the Ligated Left Circumflex Artery*.—

Group A The oxygen content of the aortic, pulmonic, and retrograde coronary artery blood varied from dog to dog. However, the retrograde coronary arterial blood was always highly oxygenated and its oxygen content invariably approximated that of simultaneously drawn aortic blood. The oxygen content of the blood obtained from the distal cut end of the ligated circumflex artery ranged from 8.1 to 18.0 volumes per cent with an average of 14.3 volumes per cent. Concomitant samples of aortic blood ranged from 7.2 to 18.8 volumes per cent with an average of 15.9 volumes per cent (see Table II).

Group B The findings in this group were almost identical to those of Group A. The oxygen content of the retrograde circumflex blood samples varied from dog to dog. The blood was invariably highly oxygenated and always approximated the oxygen content of aortic blood. These values ranged from 11.4 to 24.0 volumes per cent with an average of 16.6 volumes per cent. Concomitant samples of aortic blood ranged from 10.7 to 22.4 volumes per cent with an average of 16.5 volumes per cent (see Table II).

TABLE II. OXYGEN CONTENT OF THE RETROGRADE BLOOD FROM THE DISTAL CUT END OF THE LIGATED CIRCUMFLEX ARTERY

NORMAL DOGS					
	O_2 CONT RETROGR COR ART (VOL %)	O_2 CONT AORTIC BLOOD (VOL %)	O_2 CAP AORTIC BLOOD (VOL. %)	% SAT'N AORTIC BLOOD	O_2 CONT PUL ART (VOL %)
1	17.3	18.8			10.2
2	15.1	15.8	16.8	94.8	12.6
3	17.5	18.2	18.2	100.0	12.2
4	14.7	16.2	16.7	100.0	10.9
5	15.8	16.9	17.8	94.9	14.5
6	18.0	17.5	17.8	98.3	11.5
7	15.4	16.3	17.1	95.3	11.6
8	8.1	7.2	12.2	59.8	4.8
9	11.6	11.5	17.4	66.0	8.6
10	11.9	14.7	19.5	75.4	9.5
Average	14.5	15.3			10.6

DOGS WITH PREVIOUS CARDIAC SURGERY			
	O_2 CONT RETROGR COR ART (VOL %)	O_2 CONT AORTIC BLOOD (VOL. %)	O_2 CON PUL AR (VOL
1	17.3	16.4	12.[illegible]
2	24.0	23.4	20.[illegible]
3	11.4	10.7	4.[illegible]
4	17.8	18.0	11.9
5	14.0	14.5	10.[illegible]
Average	16.6	16.5	10.[illegible]
Left Anterior Descending Art			
6	18.3	17.2	10.1
7	13.6	15.0	10.0
8	14.9	14.9	10.1
9	18.0	17.1	1[illegible]
10	17.2	17.5	10.5
Average	16.4	16.3	10.5

3. *Mean Coronary Sinus Pressure and Oxygen Content.*—

Group A. The mean coronary sinus pressure ranged from 2 to 12 cm. of water with an average of 6.1 cm. of water. The coronary sinus blood oxygen content ranged from 1.0 to 9.2 volumes per cent with an average of 4.5 volumes per cent (see Table III).

TABLE III. MEAN CORONARY SINUS PRESSURE AND OXYGEN CONTENT OF CORONARY SINUS BLOOD

	NORMAL DOGS		DOGS WITH PREVIOUS CARDIAC SURGERY	
	COR SINUS PRESSURE (CM H_2O)	O CONT COR SINUS (VOL %)	COR SINUS PRESSURE (CM H_2O)	O CONT COR SINUS (VOL. %)
1	12.0	9.2	5.4	
2	4.0	6.3	6.0	
3	2.0	6.7	(23.0)	
4	5.0	4.4	12.0	
5	8.6	2.9	6.4	4.8
6	8.4	7.4	4.0	4.2
7	4.6	2.6	4.0	
8	4.0	1.0	7.0	
9	7.0	2.4	7.2	
10	5.0	1.2	10.0	
Average	6.1	4.5	6.7	

Group B. The mean coronary sinus pressure ranged from 4.0 to 12 cm. of water with an average of 6.7 cm. of water. Dog 3, Group B, had a mean coronary sinus pressure of 23 cm. of water. It is not included in this average since it was in severe right heart failure and was included only to determine the effect of elevated coronary sinus pressure without sinus occlusion upon retrograde coronary artery bleeding. Coronary sinus blood oxygen content was determined in two dogs and was 4.8 and 4.2 volumes per cent, respectively (see Table III).

4 *Mortality of Circumflex Coronary Artery Ligation* —

Group A Ligation of the circumflex branch of the left coronary artery at its origin in a series of ten normal dogs was associated with a 100 per cent mortality Nine of the ten dogs died of ventricular fibrillation within the first thirty minutes following circumflex arterial ligation The majority of them developed ventricular fibrillation within the first few minutes following ligation One dog died thirty six hours postoperatively

Group B In the group of dogs (1 to 5) in which nondescript surgery had been performed previously, after the circumflex branch was ligated, four died of ventricular fibrillation within twenty minutes, and one survived for forty days In the group (6 to 10) in which the left anterior descending artery was ligated, one died of cardiac arrest in seventeen minutes one died of ventricular fibrillation within twenty minutes, one died in forty eight hours, two survived until sacrificed In both survivors (Dogs 9 10, Group B, Table I), a large accessory anterior descending artery arising from the circumflex was demonstrated, and in both the value of the retrograde blood flow from the distal cut end of the vessel was excessively high.

DISCUSSION

The results obtained in this experiment emphasize several points Most important is the fact that the retrograde blood obtained from the distal segment of the ligated circumflex coronary artery in the normal dog is highly oxygenated and arterial in nature In all instances, its oxygen content approximates the values of blood specimens simultaneously obtained from the aorta Since the blood flow from the distal segment of the ligated artery is continuous and of high oxygen content, its source must be from neighboring coronary arteries This retrograde blood flow from the distal segment of the ligated coronary artery in dogs undoubtedly arises from small interarterial communications, and represents interarterial coronary collateral flow Therefore, quantitating the retrograde coronary arterial flow provides an accurate method of measuring and comparing interarterial coronary collateral flow This method of quantitating interarterial coronary collateral flow is useful in evaluating the effect of cardiac procedures designed to increase the collateral circulation of the heart in occlusive coronary artery disease

In those dogs which had had previous nondescript cardiac surgery, with formation of pericardial adhesions, the findings were similar to those in the normal dogs The retrograde blood flow from the distal segment of the ligated circumflex artery was arterial in nature and small in quantity, measuring approximately 1 9 c c per minute Thus, nondescript cardiac surgery, per se does not noticeably stimulate an increase in the interarterial coronary collateral flow

The mean coronary sinus pressure under the conditions of our experiment averaged 6 1 cm of water and the oxygen content of coronary sinus blood averaged 4 5 volumes per cent This was similar to the findings of Gregg and associates[1-4] in their studies

In Dog 3, Group B, the mean coronary sinus pressure was elevated because of severe right heart failure The retrograde circumflex coronary arterial flow was similar to that in the normal dogs According to Eckstein and coworkers progressive elevation in coronary sinus pressure produces proportionate increase in retrograde coronary flow

The mortality in these experiments, from ligation of the circumflex branch of the left coronary artery was 100 per cent Ligation of the left anterior descending branch in our series of dogs produced a 60 per cent mortality This was similar to the mortality following left anterior descending coronary ligation in normal dogs reported by Hahn and Beck[5] The incidence of the occurrence of an accessory left anterior descending coronary artery in our series was 40 per cent, which corresponds with the survival rate It is possible that the survival from ligation of the anterior descending branch of the coronary artery in our experiments, and in those of Hahn and associates, are attributable to the fortuitous presence of such accessory branches

SUMMARY

1 An accurate method of measuring interarterial coronary collateral flow is described

2 Retrograde coronary arterial blood flow and the oxygen content of blood obtained from the distal segment of the circumflex coronary artery have been determined in a series of normal dogs Similar studies were performed in a second series of dogs in which nondescript cardiac surgery had been previously performed

3 In both groups, the retrograde bleeding was of small quantity and arterial in nature, always approximating the oxygen content of aortic blood This retrograde blood flow is believed to be due to interarterial coronary collateral circulation

4 The mortality due to ligation of the circumflex branch of the left coronary artery in ten normal dogs was 100 per cent The mortality due to ligation of the left anterior descending artery was 60 per cent The higher survival rate in the latter group may be due to the high incidence in this small series of an accessory left anterior descending coronary artery arising from the circumflex branch of the left coronary artery

The authors wish to express their appreciation to Miss Betty Underwood and Miss Ruth Freeman for invaluable technical assistance

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PROTECTION OF THE HEART BY ARTERIALIZATION OF THE CORONARY SINUS

II. Coronary Flow in Dogs With Aorticocoronary Sinus Anastomosis

Alvin A. Bakst, M.D., Jaime Costas-Durieux, M.D., Harry Goldberg, M.D.,
and Charles P. Bailey, M.D.
Philadelphia, Pa.

THIS is a continuation of previous studies undertaken to investigate and evaluate the benefits to the heart in occlusive coronary artery disease afforded by arterialization of the coronary sinus. The original conception for the revascularization of the myocardium was first described by Pratt[1] in 1898, who perfused the coronary sinus of a freshly extirpated cat's heart with defibrinated arterialized blood, and was able to maintain regular coordinated contractions for one and one-half hours. Gross and associates[2] demonstrated that ligation of the coronary sinus in dogs elevated the coronary sinus pressure. This procedure was associated with a very low operative mortality. They demonstrated a reduction in the mortality and size of infarcts following major coronary artery occlusion in sinus-ligated dogs. Roberts and co-workers[3] demonstrated in dogs that following the creation of an arteriovenous anastomosis between a systemic artery and the coronary sinus, forceful cardiac action was maintained for as long as twenty-six hours following coronary artery ligation.

Stenstrom,[4] in dogs with sinus arterialization, demonstrated a reduction in the number of infarcts and incidence of ventricular fibrillation following coronary artery ligation. Hahn and Beck[5] have demonstrated a marked benefit afforded by coronary sinus arterialization in major coronary artery ligation in dogs.

The procedure developed by Beck and his associates is aimed at the revascularization of the heart in occlusive coronary artery disease. It utilizes the placement of a free vein graft between the aorta and the coronary sinus, followed by the subsequent partial ligation of the coronary sinus immediately proximal to its entrance into the right atrium. This second stage of the procedure prevents the complete egress of the blood into the right atrium, and forces a portion of the aortic blood into the venous tree.

Arterialization of the coronary sinus has been demonstrated to protect the heart from ventricular fibrillation following coronary artery ligation.[10, 11] It also reduces the number and size of myocardial infarctions in those dogs surviving coronary artery ligation as well as favorably altering the survival rate in these experiments. Bailey and co-workers[13] have demonstrated that

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anatomically, fluid introduced into the coronary sinus may reach the capillary bed in retrograde fashion. However, it remains to be proved that following coronary artery ligation the protection afforded by coronary sinus arterialization is on the basis of retrograde myocardial capillary flow, with improvement of myocardial oxygenation.

Inasmuch as the arteriovenous tree is continuous both directly and via the capillary bed, it seemed reasonable that a portion of the arterial blood introduced into the coronary sinus following sinus arterialization might be recovered in retrograde fashion from the distal end of a transected coronary artery. In order to determine the effects of arterialization of the coronary sinus on this retrograde coronary arterial blood flow, it was first necessary to establish normal control values for the quantity and oxygen content of this retrograde coronary arterial blood. Moreover, we have repeated these experiments in a series of control animals having had previous nondescript cardiac surgery to analyze the effect of previous cardiac surgery and pericardial adhesions on the retrograde coronary arterial blood flow and oxygen content. When possible, animals having had previous unsuccessful aorticocoronary sinus anastomoses, with thrombosis of the graft, were utilized.

At this point, having established control values in our series of normal dogs and those with previous nondescript cardiac surgery, we repeated these experiments in dogs protected by aorticocoronary sinus anastomoses with the graft open and closed.

METHOD

Ten mongrel dogs were first prepared with arterialization of the coronary sinus using the two stage operation developed by Beck, and modified by us. At a first stage, through a left-sided approach, an external jugular vein graft was placed between the aorta and the coronary sinus. Three to four weeks later, through a right sided approach, the coronary sinus was partially ligated over a probe to 2 to 3 mm. Four to eight weeks following the second stage of the procedure physiologic data were obtained. The animals were anesthetized with Halital, after which artificial respiration was maintained using intermittent positive pressure through an endotracheal tube. The left chest was entered through the fourth intercostal space, and dense pleural and pericardial adhesions were divided. The vein graft was dissected, and examined for patency. Only dogs with patent grafts were used. An umbilical tape was passed around the graft to facilitate its easy occlusion at the appropriate time during the procedure. A needle tipped polythene catheter connected to a water manometer was inserted into the coronary sinus, after which coronary sinus pressure and blood samples for oxygen content were obtained (Fig. 1). The circumflex branch of the left coronary artery was carefully dissected to its origin, and ligated. The artery was cannulated distal to the ligature, and a sample of retrograde blood was collected (Fig. 2). Simultaneous blood samples were taken from the aorta and the pulmonary artery. The minute volume of retrograde blood flow was then recorded. At this point the graft was occluded and the experiment was repeated (Figs. 3 and 4). This was the method used for

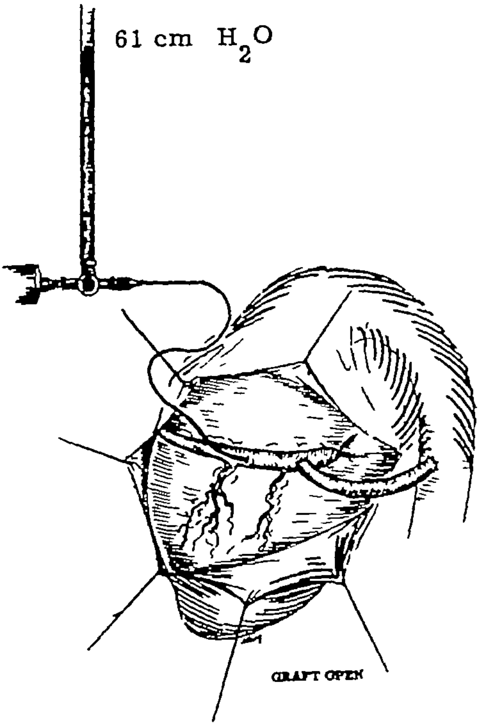

Fig 1 —A needle-tipped polythene catheter attached to a water manometer is inserted into the coronary sinus proximal to the site of partial ligation Coronary sinus pressure l frequently above the recordable level of the manometer when its base is maintained leve with the sinus The recorded readings are corrected by raising the base of the manomete above the coronary sinus level measuring the distance and adding it to the manometric reading

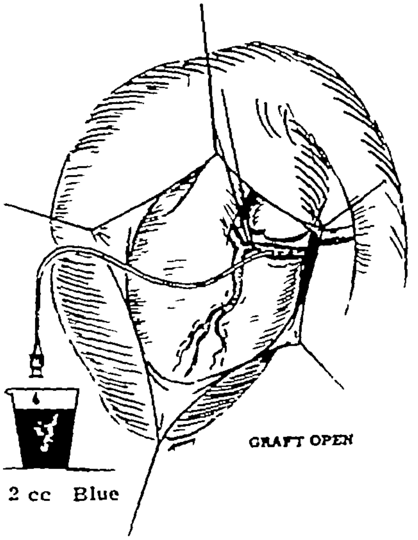

Fig 2 —The circumflex branch of the left coronary artery is carefully dissected to its origin where it is ligated An incision is made in the artery distal to the ligature and a polythene catheter is inserted Retrograde blood flow from this distal cannulated segment of circumflex coronary artery is recorded and blood samples are secured for the determination of oxygen content.

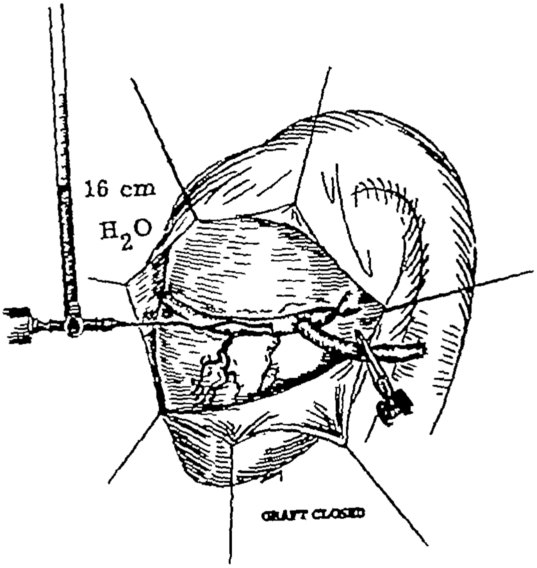

Fig 3—A needle tipped polythene catheter was previously inserted into the coronary sinus proximal to the site of partial ligation This catheter is attached to a water manometer The aorta to coronary sinus vein graft is occluded and the fall in coronary sinus pressure is recorded Following the occlusion of the graft a period of two minutes is permitted to elapse before a blood specimen is secured for determination of blood oxygen content.

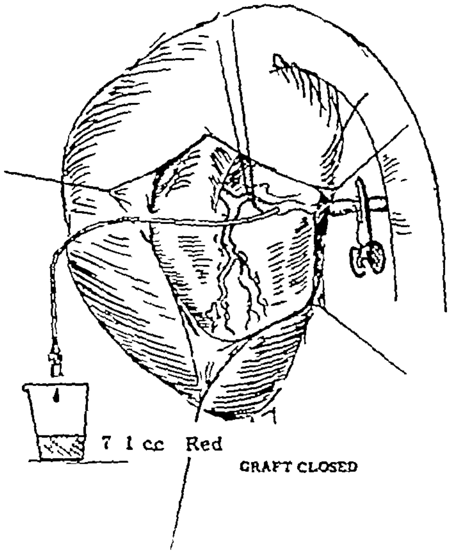

Fig 4—The left circumflex artery was previously ligated at its origin and the distal segment was cannulated with a polythene catheter Following the occlusion of the aorta to coronary sinus vein graft the distal end of the transected coronary artery is permitted to bleed freely through the cannula for a period of two minutes during which time minute blood flow is recorded At the end of this interval of time a blood sample is secured for the determination of blood oxygen content.

TABLE I. RETROGRADE BLOOD FLOW AND OXYGEN CONTENT OF BLOOD FROM THE DISTAL END OF THE TRANSECTED LEFT CIRCUMFLEX CORONARY ARTERY IN SINUS ARTERIALIZED DOGS WITH THE GRAFT OPEN AND CLOSED

DOG NO.	GRAFT OPEN				GRAFT CLOSED							
	RETR. COR. ART.		CORONARY SINUS		RETR. COR. ART.		CORONARY SINUS		AORTIC BLOOD			PUL. ART.
	FLOW (C.C./MIN.)	O$_2$ CONT. (VOL. %)	PRESS. (CM. H$_2$O)	O$_2$ CONT. (VOL. %)	FLOW (C.C./MIN.)	O$_2$ CONT. (VOL. %)	PRESS. (CM. H$_2$O)	O$_2$ CONT. (VOL. %)	CONT. (VOL. %)	CAP. (VOL. %)	SAT'N (%)	O$_2$ CONT. (VOL. %)
	Blood Drawn Immediately Following Occlusion of Graft											
1	9.6	9.0	15						15.2			10.3
2	9.0	1.9	80	17.2	7	5.3			18.8	20.6	91.3	11.4
3	11.0	11.8	60	12.5					19.2	20.7	92.8	15.9
4	12.0	6.1	36	12.4	10	7.7			14.0	15.8	99.6	11.1
5	12.0	1.5	60	9.7	7	4.6	20		12.1	13.0	93.1	10.2
	Blood Drawn Two Minutes Following Occlusion of Graft											
6	10.0	4.8	71	15.5	2	12.5	9		17.7	18.4	96.2	14.3
7	18.0	[illegible]	64	11.9	8	13.2	19	7.1	14.3	14.0	100.0	9.2
8	10.0	15.1	59	17.9	8	18.5	18		22.5	22.5	100.0	19.1
9	11.0	4.8	68	13.2	7	15.3	16	1.7	17.2	20.1	85.6	7.6
10	16.0	3.9	70	15.6	8	17.0	14	1.9	17.8	19.8	89.9	11.6
	Average											
	12.2	6.3	61	14.0	7.1	15.5	16	3.6	17.0			12.1

the study of the first five dogs. During the experiment on the sixth animal following the occlusion of the vein graft the cannula was inadvertently dislodged from its position in the distal circumflex artery. It was noted that the retrograde arterial blood, which was blue prior to the clamping of the graft remained so immediately thereafter. The graft remained occluded during the period of time which elapsed while the artery was recannulated. At the end of this period of time it was observed that the retrograde blood had changed from blue to red. Consequently, in Dogs 6 to 10, following the occlusion of the graft the distal circumflex artery was permitted to bleed freely for two minutes prior to the collection of blood samples for oxygen content.

RESULTS

1. *Retrograde Blood Flow From the Distal Cut End of the Ligated Circumflex Branch of the Left Coronary Artery.*—The results are shown in Table I. With the graft open, retrograde blood flow ranged from 9.0 to 18.0 c.c. per minute, with an average of 12.2 c.c. per minute.

Following the occlusion of the aorticocoronary sinus vein graft, the retrograde circumflex artery blood flow fell significantly in each dog. These values ranged from 2 to 10 c.c. per minute with an average of 7.1 c.c. per minute.

2. *Oxygen Content of the Retrograde Blood Collected From the Distal End of the Transected Circumflex Artery.*—The results are shown in Table I. Although the oxygen content of this blood varied widely from dog to dog the character of this blood remained invariable. The values for the oxygen content of this retrograde blood ranged from 1.5 to 15.1 volumes per cent with an average of 6.3 volumes per cent. Concomitant samples of aortic blood ranged from 12.1 to 22.5 volumes per cent with an average of 17.1 volumes per cent.

Despite the wide range of values of these blood samples, the retrograde circumflex arterial blood was constantly venous in nature and its oxygen content invariably much lower than pulmonary arterial blood. Moreover, the oxygen content of this retrograde circumflex arterial blood was within the limit of the values usually seen in normal coronary sinus blood. In fact, the average oxygen content of the retrograde circumflex arterial blood was 6.3 volumes per cent which compares favorably with the average value for the oxygen content of normal coronary sinus blood, which was 4.5 volumes per cent.

Following the clamping of the vein graft the values obtained for the oxygen content of the retrograde circumflex arterial blood divide themselves into two groups. The first group consists of Dogs 1 to 5 in which the blood was collected immediately following the clamping of the graft. The second group consists of Dogs 6 to 10 in which the ligated circumflex artery was permitted to bleed freely in retrograde fashion for a period of two minutes prior to the collection of the blood samples. Inasmuch as these two sets of values are significantly different we are reporting them separately. In Dogs 1 to 5, the oxygen content of the retrograde circumflex blood ranged from 4.6 to 7.7 volumes per cent with an average of 5.8 volumes per cent. These values are almost identical with the values of retrograde blood oxygen content with the graft open. However, upon careful analysis of the data from the individual dogs in each case there is a significant rise in the oxygen content of the retrograde circumflex arterial blood immediately after the graft is occluded. In Dog 2, retrograde circumflex blood oxygen content was 1.9 volumes per cent with the graft open and rose to [illegible] volumes per cent immediately after it was clamped; in Dog 4 the value rose from 6.1 to 7.7 volumes per cent, in Dog 5, from 1.5 to 4.6 volumes per cent. We believe it probable that were the artery permitted to bleed freely in retrograde fashion for two minutes, the values obtained in Dogs 1 to 5 would have risen further toward the content of arterial blood, and would have more closely resembled the findings in Dogs 6 to 10.

The second group of animals (6 to 10) consists of those in which the distal cut end of the ligated circumflex artery was permitted to bleed freely in retrograde fashion for a period of two minutes prior to the collection of the blood samples. In this group, the retrograde circumflex arterial blood oxygen content ranged from 12.5 to 18.5 volumes per cent, with an average of 15.5 volumes per cent. Despite the wide range of values, the retrograde circumflex arterial blood oxygen content compares favorably with that of aortic blood. Concomitant samples of aortic blood in Dogs 6 to 10 ranged from 14.3 to 22.5 volumes per cent, with an average of 17.9 volumes per cent. Of significance is the fact that the blood oxygen content of the retrograde circumflex arterial blood rose significantly from an average of 6.3 volumes per cent with the graft open to an average of 15.5 volumes per cent following occlusion of the graft and changed in appearance from dark venous to bright arterial blood.

3. *Mean Coronary Sinus Pressure and Blood Oxygen Content.*—With the graft open, mean coronary sinus pressure ranged from 36 to 80 cm. of water with an average of 61 cm. of water. The oxygen content of the arterialized coronary sinus blood ranged from 9.7 to 17.9 volumes per cent with an average of 14.0 volumes per cent. It may be seen in Fig. 5 that there is no direct relationship between the retrograde circumflex arterial blood flow and coronary sinus pressure.

Following occlusion of the aorticocoronary sinus graft, sinus pressure fell significantly toward but not quite to normal. The pressures ranged from 9 to 20 cm. of water with an average of 16 cm. of water.

In a few dogs coronary sinus blood samples were drawn two minutes after the graft was clamped. The values for the oxygen content of these samples ranged from 1.7 to 7.1 volumes per cent, with an average of 3.6 volumes per cent. Thus in these animals after the graft was clamped the coronary sinus blood oxygen content fell from values within arterial range to values within normal sinus range.

DISCUSSION

The most striking finding of the experiment revolves around the marked change in the amount and nature of the retrograde blood from the distal segment of the ligated and transected circumflex coronary artery in sinus arterialized dogs is opposed to those in normal dogs. In our previous communication retrograde circumflex arterial blood flow in the normal animal ranged from 0.4 to 5.0 c.c. per minute, and averaged 1.7 c.c. per minute. The oxygen content of this blood ranged from 8 1 to 18 0 volumes per cent with an average of 14 5 volumes per cent Thus, in the normal animal, retrograde circumflex arterial bleeding from a point distal to the ligature is small in quantity, and is invariably arterial in nature The findings were similar in dogs having had nondescript cardiac procedures The arterial nature of this retrograde bleeding from the distal cut end of the ligated circumflex artery signifies that the origin of this blood is arterial It undoubtedly originates in the nonoccluded coronary arteries and reaches the distal ligated coronary artery through small interarterial anastomoses Thus measurement of the retrograde coronary arterial blood flow from the distal end of the ligated and transected coronary artery is a measure of the existing intercoronary arterial anastomotic flow This was scant in the normal dog and was unchanged in those dogs having had previous nondescript cardiac operations

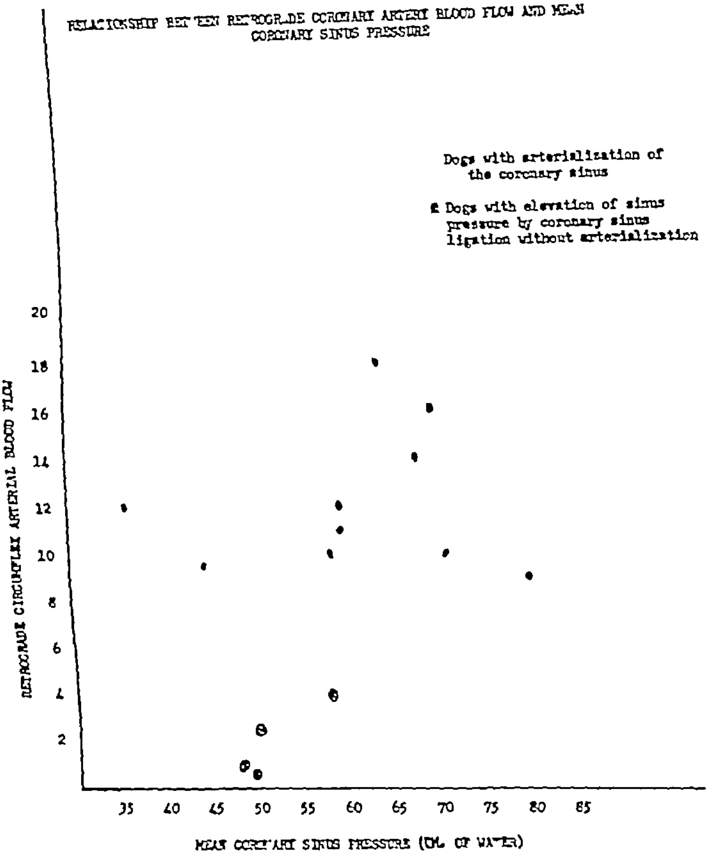

Fig 5—Retrograde circumflex arterial blood flow is plotted against the mean coronary sinus pressure The scatter pattern of the graft does not suggest any direct relationship of the two in this series of experiments

These findings were strikingly altered following arterialization of the coronary sinus for four to eight weeks Following coronary sinus arterialization, the quantity of retrograde circumflex arterial blood flow increased markedly from a normal average of 1.7 c.c. to 12.2 c.c. per minute. Arterialization of the coronary sinus also precipitated a change in the oxygen content of this retrograde circumflex arterial blood from a normal average content of 14.5 volumes per cent to 6.3 volumes per cent. These findings unmistakably attest to the increase in the retrograde circumflex arterial flow following aorticocoronary sinus anastomosis. This increase in the retrograde coronary arterial blood flow was similarly noted by Hahn and associates,[7-9] who found that in dogs with coronary sinus arterialization, but with the graft occluded retrograde coronary arterial bleeding was red and of small quantity. With the graft open retrograde bleeding increased in quantity, and the blood was blue. Eckstein and co-workers,[10, 11] in experiments on the acutely arterialized coronary sinus have demonstrated a similar increase in the retrograde flow from the distal cut end of the circumflex artery. In their experiments, the acute arterialization of the coronary sinus was effected by using a glass cannula to connect a systemic artery to the coronary sinus. They injected P32 into the coronary sinus, and in thirteen seconds recovered it from the distal ligated coronary artery.

It should be noted that with the graft open, and the coronary sinus arterialized, the oxygen content of coronary sinus blood averaged 14.0 volumes per cent and the pressure averaged 61 cm. of water. Thus, highly oxygenated blood was delivered to the coronary sinus under high pressure. Of extreme significance is the fact that blood collected from the distal cut end of the ligated circumflex artery in the sinus-arterialized dogs of four to eight weeks' duration is venous in character, its oxygen content falling within the range of normal coronary sinus blood. This is in contrast to the normal dog, in which it is arterial. We have demonstrated that nonspecific cardiac procedures per se do not alter the quantity or the nature of the retrograde blood found in the normal animal. The change in character and quantity of the retrograde blood follows coronary sinus arterialization, and is accomplished by elevation of the mean coronary sinus pressure to arterial levels (61 to 70 cm. of water), and by the introduction of highly oxygenated blood into the coronary sinus.

Under these circumstances, the blood recovered from the distal cut end of the circumflex artery is large in quantity and of low oxygen content. The low oxygen content of this blood is in the magnitude of normal coronary sinus blood oxygen content and demonstrates that it has traversed the capillary bed with extraction of oxygen by the myocardium.

In the normal animal, the pressure gradient falls from the arterial to the venous end of the capillary bed. This procedure elevates coronary sinus pressure thereby completely altering the normal pressure gradient, and favoring the retrograde flow of oxygenated blood. Following occlusion of the graft the pressure gradients again favor the normal direction of flow, and an almost normal situation is obtained. Coronary sinus pressure falls toward but not quite to normal and retrograde coronary artery bleeding again becomes arterial in nature, both simulating the normal dog (Fig. 6). It may be significant that coronary sinus pressure does not fall to normal. Gregg and associates[1] have demonstrated that following coronary sinus ligation retrograde bleeding from the distal cut end of the descending ramus of the left coronary artery increased in quantity and became venous in nature They noted that following concomitant circumflex artery ligation the back flow from the left anterior descending artery decreased appreciably It may be inferred that the residual elevation of coronary sinus pressure may be a factor in the increased retrograde circumflex arterial blood flow following occlusion of the graft Eckstein and coworkers[11] have demonstrated a proportionate relationship between the retrograde arterial bleeding and coronary sinus pressure in their acute experiments

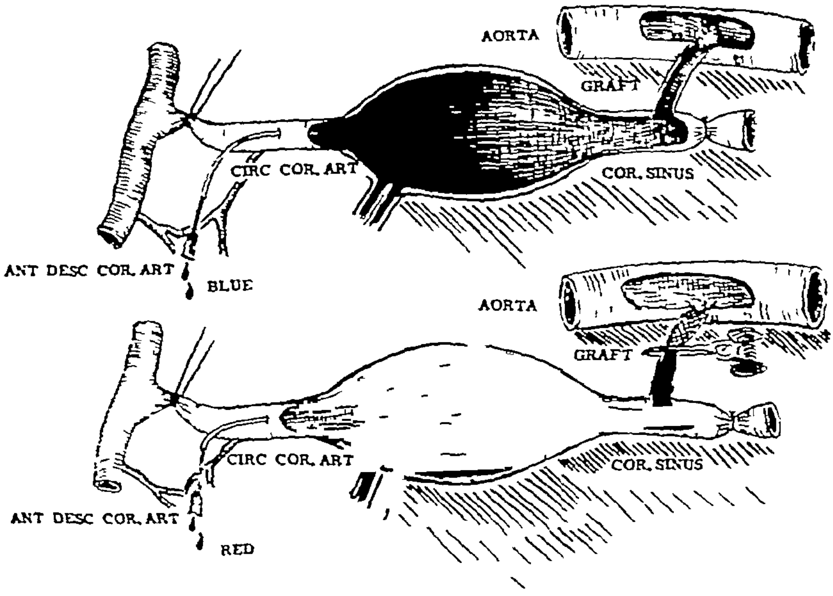

Fig 6 —A Aorta to coronary sinus anastomosis produces an elevation of coronary sinus pressure and introduces highly oxygenated blood into the coronary sinus This alters the normal pressure gradient, and favors the retrograde flow of a portion of this oxygenated blood

B Following occlusion of the graft, the pressure gradient again favors the normal direction of flow and an almost normal situation is obtained. Coronary sinus pressure falls toward normal and retrograde blood from the distal segment of the coronary artery again becomes arterial in nature both simulating the normal dog

We did not note this relationship in dogs in which the coronary sinus had been arterialized for four to eight weeks (Fig 5) In addition in several animals in which the coronary sinus pressure was elevated to 48 to 58 cm of water by complete sinus occlusion retrograde circumflex arterial blood flow averaged 2 5 c c[1] Although coronary sinus pressure was elevated eight to ten times above normal the flow from the distal cut end of the circumflex artery was within normal range

Following occlusion of the graft the volume of retrograde coronary arterial bleeding from the distal cut end of the circumflex artery falls from 12 2 c c per minute with the graft open to 7 1 c c per minute This blood is highly oxygenated and arterial in nature and undoubtedly represents blood arising from intercoronary anastomotic flow. Retrograde bleeding in our normal group was 1.7 c.c. per minute as opposed to an average of 7.1 c.c. per minute in this group. This represents a fourfold increase above the expected normal values and probably represents a significant increase in the intercoronary arterial anastomotic flow.

When retrograde bleeding from the distal cut end of the circumflex artery is permitted in sinus arterialized dogs with the graft open, these values rise still higher to an average of 12.2 c.c. per minute. This blood is of very low oxygen content, averaging 6.3 volumes per cent. It is therefore unlikely that the retrograde blood flow with the graft open is significantly contributed to by blood arising from intercoronary anastomoses because of the low oxygen content of this blood. It is more probable that this increased retrograde blood flow from the distal cut end of the ligated circumflex artery represents retrograde flow from the coronary sinus. The venous nature of this blood is incontrovertible evidence that it has traversed the myocardial capillary bed, where its oxygen was extracted.

In our experiments on sinus-arterialized dogs, we have observed that following circumflex coronary artery ligation, the heart continued to beat in vigorous, uninterrupted fashion. Whereas we found it imperative to expedite the collection of data in the normal animals before ventricular fibrillation ensued, we soon learned that we could proceed more deliberately in the sinus arterialized animals, provided the graft was functioning. However, when the graft was occluded, data had to be obtained with dispatch lest the heart fibrillate. In several dogs in which the heart beat well for considerable periods of time following circumflex arterial ligation ventricular fibrillation ensued within five minutes after the graft was clamped. This observation further emphasized the value of the protection afforded by the aorta to coronary sinus anastomosis. These observations are in accordance with those found by others.

Thus, in our experiments we have demonstrated three salient findings which elucidate the protection to the heart afforded by arterialization of the coronary sinus of four to eight weeks' duration following circumflex artery ligation. (1) The myocardial capillary bed is perfused in retrograde fashion, (2) the myocardium is capable of extracting oxygen from blood supplied to it in retrograde fashion, and (3) there is a significant increase in the intercoronary arterial anastomotic flow.

SUMMARY AND CONCLUSIONS

1. Retrograde blood flow and oxygen content from the distal cut end of the ligated and transected circumflex artery have been determined in sinus arterialized dogs with the graft open and closed.

2. When the graft was open, coronary sinus pressure was high and coronary sinus blood was of high oxygen content.

3. With the graft open the backflow from the distal cut end of the circumflex coronary artery was of much greater quantity than normal, was of low

oxygen content and was venous in nature This demonstrated a reversal of blood flow through the capillary bed with extraction of oxygen by the myocardium

4 When the graft was occluded, coronary sinus pressure fell significantly, and the blood oxygen content fell to normal coronary sinus levels Concomitantly, there was a significant fall in the retrograde circumflex arterial blood flow, which returned to normal arterial blood of high oxygen content This blood flow was four times greater than the expected normal, and was believed to represent a significant increase in the interarterial coronary collateral anastomoses

5 The physiologic explanation of the protection to the heart afforded by coronary sinus arterialization is believed to be threefold (a) The myocardial capillary bed is perfused in retrograde fashion with arterial blood, (b) the myocardium is capable of extracting oxygen from the blood supplied to it in retrograde fashion, and (c) there is a significant increase in the blood flow occurring via intercoronary arterial anastomoses

The authors wish to express their appreciation to Miss Ruth Freeman and Miss Betty Underwood for their technical assistance

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THE ARTERIAL OXYGEN AND CARBON DIOXIDE TENSION DURING THE POSTOPERATIVE PERIOD IN CASES OF PULMONARY RESECTIONS AND THORACOPLASTIES

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AFTER a lobectomy has been performed, there is frequently some degree of anoxia for a week. This may be due to poor re-expansion of the remaining lobe or to poor ventilation on the operated side for some time after the operation. In cases of total pneumonectomy, Maier and Cournand (1943) found that the oxygen saturation of the arterial blood returned to a normal level within a few days after operation. In cases of thoracotomies and abdominal operations no anoxia was encountered.

We have observed several instances where five-rib thoracoplasties with apicolysis resulted in more severe postoperative courses than resections in similar cases. This must be due to the combination of compression atelectasis produced by the thoracoplasty and the accumulation of fluid in the apicolysis space plus paradoxical movements of the unstable chest wall. For some time following the operation there is perfusion of nonventilated lung parenchyma due to atelectasis and poor ventilation of the aerated parenchyma on the operated side due to the paradoxical movements and pain.

In this article we wish to report the changes in the arterial oxygen and carbon dioxide tension during the immediate postoperative period in cases of pulmonary resections with and without the combination of thoracoplasties. Moreover blood samples were taken during voluntary hyperventilation to determine how soon after the operation an effective hyperventilation could be performed.

The measurement of the arterial oxygen tension by the indirect method was found to be more accurate in the detection of small changes in the arterial blood than the saturation method.

METHOD

With an indwelling needle in the femoral artery a blood sample was taken at rest and after the patient had been hyperventilating as much as possible for about twenty-five seconds. Oxygen and carbon dioxide tensions (pO_2 and pCO_2) in the arterial blood were determined according to Riley, Proemmel and Franke with a slight modification. The saline or saline Dreft solution has been omitted for washing the capillary. The sodium hydroxide solution is applied for both the capillary washing and the simultaneous CO_2 combining as well, thereby eliminating one source of error. This investigation was performed before operation and at intervals during the postoperative period.

From the Sabbatsberg Hospital, Surgeon-in-chief: Professor C. Crafoord.

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RESULTS

I *Pneumonectomy*—

Five cases of pneumonectomy with different degrees of pulmonary reserve were investigated

CASE 1—In a 56 year old man a right extrapleural pneumonectomy under a seven rib thoracoplasty was performed for tuberculous empyema The left lung was healthy Maximal breathing capacity was 68 L per minute The arterial blood tension measurements in mm Hg were

	BEFORE OPERATION		13 DAYS AFTER OPERATION	
	AT REST	HYP VENT	AT REST	HYP VENT
pO_2	94 3	90 4	78 4	81 6
pCO	34 1	41 6	37 1	39 0

CASE 2—In a 30 year old man with a left tuberculous empyema and a bronchocutaneous fistula under a ten rib thoracoplasty, an extrapleural pneumonectomy was performed. Maximum breathing capacity was 80 L per minute There had been a spread to the right lung but no active contralateral tuberculosis was demonstrated at the time of operation After the operation the arterial oxygen tension was low for several days before rising, it did not reach the preoperative level until after more than one week (Fig 1)

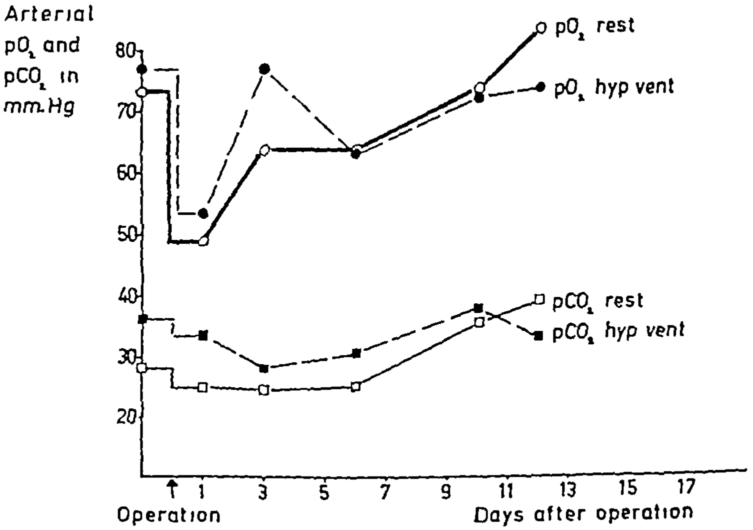

Fig 1 (Case 2)

CASE 3—In a 36 year old man a destroyed left lung was removed For five years he had had pneumothorax treatment on the right side for an upper lobe cavity Maximum breathing capacity was 47 L per minute The pressures in the pulmonary artery were normal *Residual volume was 37 4 per cent of the total lung capacity* Not until one week after the operation did the arterial oxygen tension reach the preoperative value (Fig 2) Resection of the left upper nine ribs was performed one month after the pneumonectomy

CASE 4—A 44 year old man had a right tuberculous empyema with a bronchocutaneous fistula and a left upper lobe cavity Maximum breathing capacity was 55 L per minute and his residual volume was 42 per cent Under a three rib thoracoplasty a right extrapleural pneumonectomy with resection of the fourth to the tenth rib was performed. The patient had a low arterial oxygen tension before operation and died eight days after the operation. Autopsy showed a cor pulmonale. The tensions were

	Before Operation		3 Days After Operation	
	At rest	Hyp vent	At rest	Hyp vent
pO_2	55 4	57 1	68 3	67 0
pCO	42 0	51 7	51 4	48 7

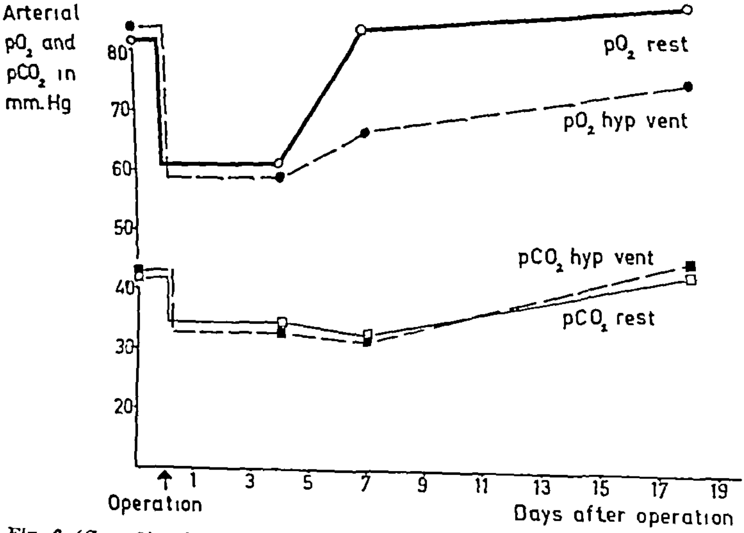

Fig 2 (Case 3) —Left pneumonectomy performed on patient with a destroyed left lung

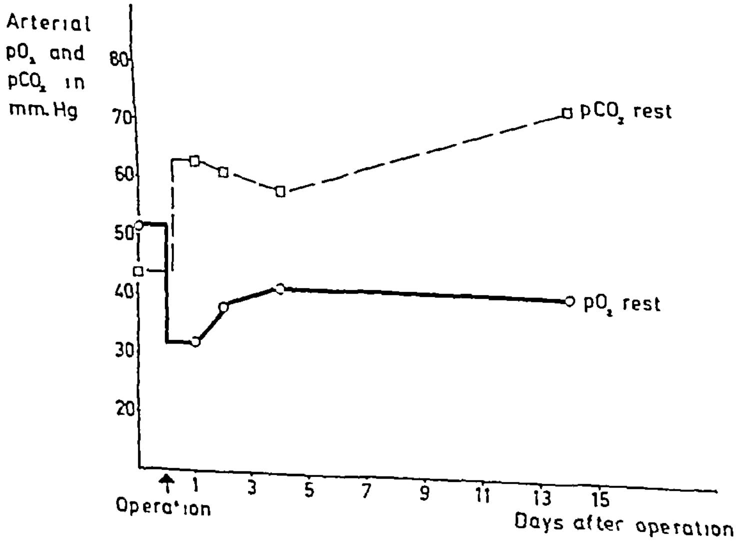

Fig 3 (Case 5)

Case 5 —A 37 year old man had a left tuberculous empyema with a bronchopleural fistula. Maximum breathing capacity was 22 L per minute. The pressure in the pulmonary artery was high. A pronounced oxygenating insufficiency was noted before operation. A left extrapleural pneumonectomy was performed After the operation the patient was markedly anoxic with carbon dioxide retention (Fig 3) He survived this operation and one and a half months later he had a left thoracoplasty with removal of the first to eighth ribs The patient was still a respiratory cripple following the operation as he was before, but he now had negligible amounts of sputum compared to the amounts before surgery This patient had the poorest pulmonary function of any who lived following the operation. One year later this man could walk slowly His maximum breathing capacity was 18 L per minute The resting arterial pO_2 was 59 3 mm Hg and pCO_2 was 58 1 mm Hg Sputum and gastric washings were negative on guinea pig test

Conclusion —After pneumonectomies a considerable decrease in the arterial oxygen tension is observed The anoxia has been found to last longer than earlier described Even in good-risk patients the preoperative arterial oxygen tension was first reached after one week, whether the pneumonectomy was done under a thoracoplasty (Fig 1) or done without thoracoplasty (Fig 2) In cases of pneumonectomy, impaired ventilation due to pain seems to be the main cause of the low arterial oxygen tension The phrenic nerve is never divided after a pneumonectomy, since the contralateral diaphragm is thought to function more efficiently if the diaphragm on the operated side is not paralyzed

II Segmental Resection Without Thoracoplasty —

Only one case was investigated in which the resection of the apical segment of the right lower lobe was performed without a thoracoplasty

CASE 6 —*The patient was a 36 year old man He had a pneumothorax on the left* The following values were found

	BEFORE OPERATION		12 DAYS AFTER OPERATION	
	AT REST	HYP VENT	AT REST	HYP VENT
pO	90 0	83 5	83 7	82 5
pCO	38 9	39 1	42 9	43 1

III Resections of Lobes and Segments With Extrapleural Plombage —

In two patients with resection of a lower lobe, an apical extrapleural plastic plomb was inserted to prevent overdistention and to improve the ventilation by bringing the upper lobe down to the diaphragm These are described in Cases 7 and 8

CASE 7 —The following values were found

	BEFORE OPERATION		2 WEEKS AFTER OPERATION	
	AT REST	HYP VENT	AT REST	HYP VENT
pO	77 5	99 6	77 0	75 1
pCO	45 4	32 8	45 8	35 5

CASE 8 —The following values were found

	BEFORE OPERATION		2 WEEKS AFTER OPERATION	
	AT REST	HYP VENT	AT REST	HYP VENT
pO	73 7	80 4	80 8	89 0
pCO	32 0	35 1	41 6	36 1

CASE 9 — A 23 year old woman underwent a right upper lobectomy combined with extrapleural plombage The values are shown in Fig 4 Six months later the plombage had to be removed due to infection which caused a bronchial fistula

Conclusion—In only Case 8 could a good hyperventilation test be performed two weeks after the operation The extrapleural plastic plombage in combination with lobectomy will prevent paradoxical movement of the chest wall Still a considerable impairment of the arterial oxygen tension was found during the first few days (Case 9, Fig 4) due mainly to pain and atelectasis

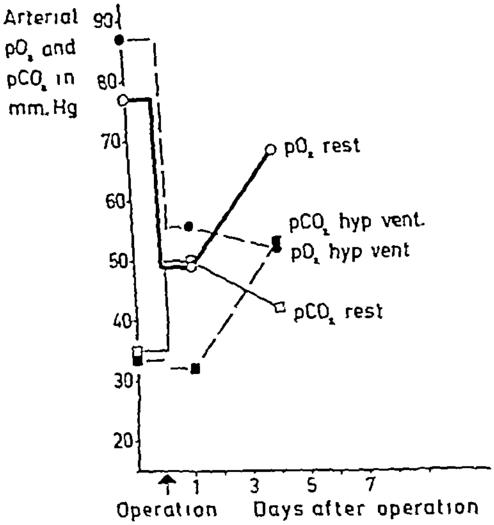

Fig 4 (Case 9)

B Resections of Lobes and Segments Under Old Thoracoplasties—In this group data were collected on sixteen patients Only two of these patients could perform a voluntary hyperventilation with an increase of the arterial oxygen tension of more than 5 mm. Hg 9 and 12 days, respectively, after the operations The preoperative arterial oxygen tension was reached between one and two weeks in nine of sixteen patients In four cases the arterial pO_2 was still between 2 and 5 mm Hg lower than before operation In three cases a lower value of more than 5 mm Hg was encountered during this period than before operation In one patient the arterial oxygen tension was only 54 2 mm Hg on the ninth day after operation as compared to 81 8 mm Hg before operation This patient had developed a bronchial fistula

Five cases with different degrees of impaired pulmonary function are described

Case 10—In a 28 year old man, under a four rib thoracoplasty a resection of the right upper lobe plus the apical segment of the lower lobe plus the fifth to the seventh ribs was performed Maximum breathing capacity was 90 l per minute The tensions are shown in Fig 5 A pronounced decrease of arterial oxygen tension was found for only a few days, and by the fifth day the preoperative value was already reached

Case 11—A 45 year old man who had had a seven rib right sided thoracoplasty and a left three rib thoracoplasty now underwent a resection of the posterior segment of the left upper lobe and a wedge of the apex of the lower lobe plus the fourth and fifth ribs

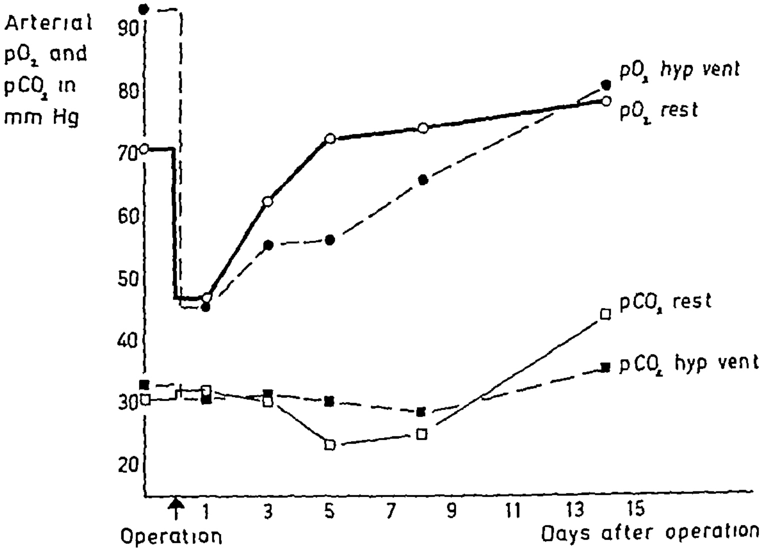

Fig. 5 (Case 10)

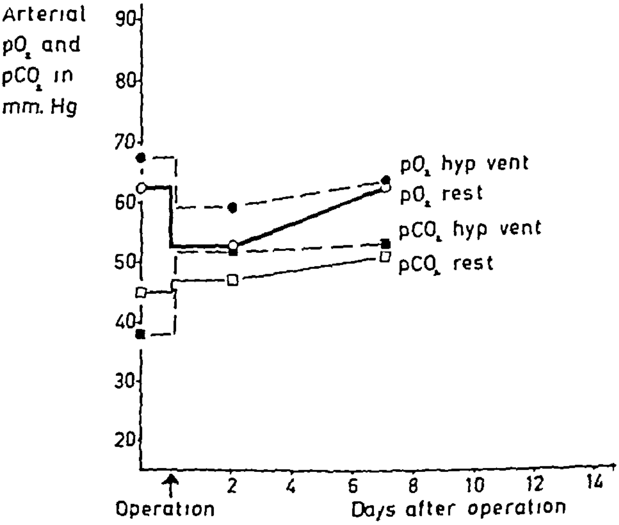

Fig. 6 (Case 11)

Maximum breathing capacity was 49 L per minute After one week the preoperative arterial oxygen tension was reached (Fig 6)

CASE 12 —A 20 year old woman had a right five-rib thoracoplasty and left extrapleural plombage Resection of the apicoposterior and anterior segment of the left upper lobe under the plombage was performed After two weeks the preoperative arterial oxygen tension was first reached (Fig 7) Three months later a resection of the right upper lobe and lateral segment of the middle lobe was performed without postoperative complications

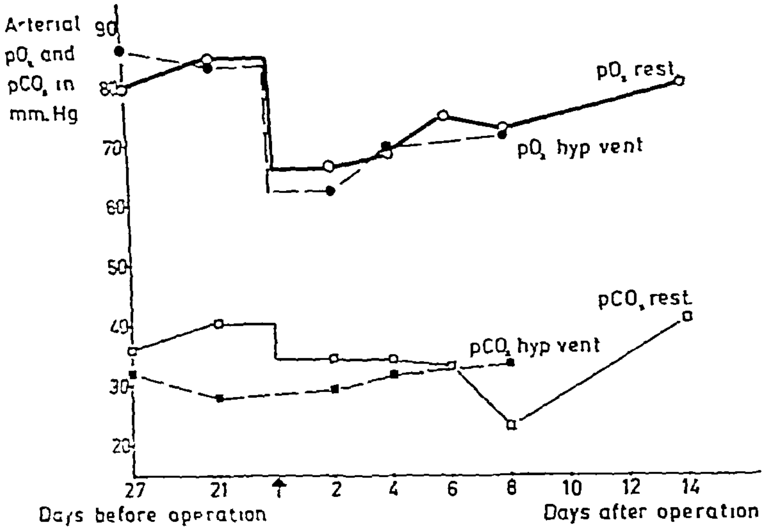

Fig 7 (Case 12)

CASE 13 —A 27 year old woman had a left upper lobectomy with decortication of the lower lobe performed under a five-rib thoracoplasty One and one-half years later the right upper lobe, a wedge from the apical segment lower lobe and the fourth and fifth ribs were resected under a three-rib thoracoplasty At the time of the last operation (right upper lobectomy) the maximum breathing capacity was 55 L. per minute The arterial oxygen tension had not reached the preoperative value fourteen days after the operation (Fig 8 A) The x-ray picture of the patient one month and twenty-two days after operation is shown in Fig 8 B One year later she was well and sputum negative

CASE 14 —A 34 year old man with a left six-rib thoracoplasty had a resection of the right upper lobe plus a wedge resection of the apical segment of the lower lobe resection of the fourth to sixth ribs performed under a 3-rib thoracoplasty Maximum breathing capacity was 44 L per minute Three days before surgery there was a short period of pulmonary edema with a simultaneous drop in arterial oxygen tension (Fig 9) The day after this episode, when the patient felt better the resting arterial oxygen tension had reached its original value again However seventeen days after the operation the original value had not been reached (Fig 9)

Conclusion —After resection under a thoracoplasty in a patient with good pulmonary function (Case 10 Fig 5) the arterial oxygen tension reached the preoperative value on the fifth day after surgery In some cases with advanced bilateral disease the arterial oxygen tension had not yet reached the preoperative value after fourteen postoperative days (Case 13 Fig 8 and Case 14 Fig 9)

V Resections of Lobes and Segments With Simultaneous Thoracoplasty.—Six patients were included in this group There were four cases of unilateral disease, in three cases only one segment was removed in contrast to Group IV In spite of the good pulmonary function in Group V, the preoperative

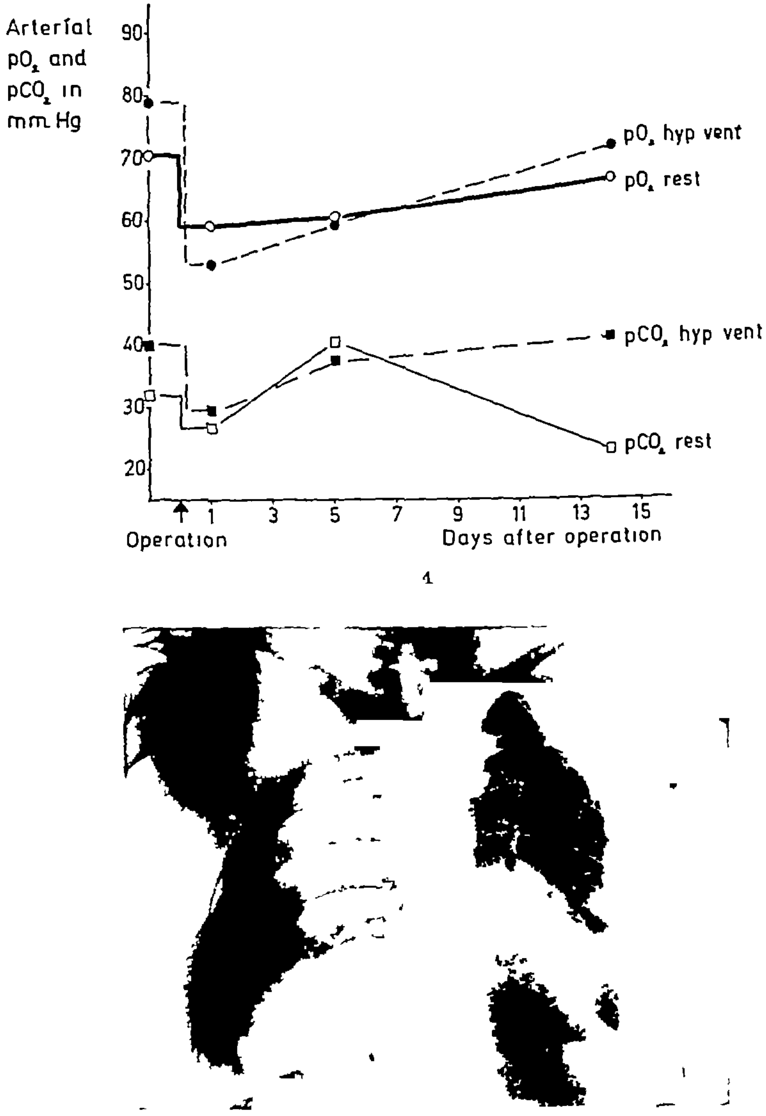

Fig 8 (Case 13)

arterial oxygen tension was reached in only one patient in one to two weeks postoperatively The simultaneous thoracoplasty with paradoxical movement of the chest wall, as well as the increased pain causing impaired ventilation can explain the prolonged postoperative lowering of the arterial oxygen tension In two cases an increase of more than 5 mm Hg in arterial oxygen tension was encountered during hyperventilation after ten and nineteen postoperative days, respectively

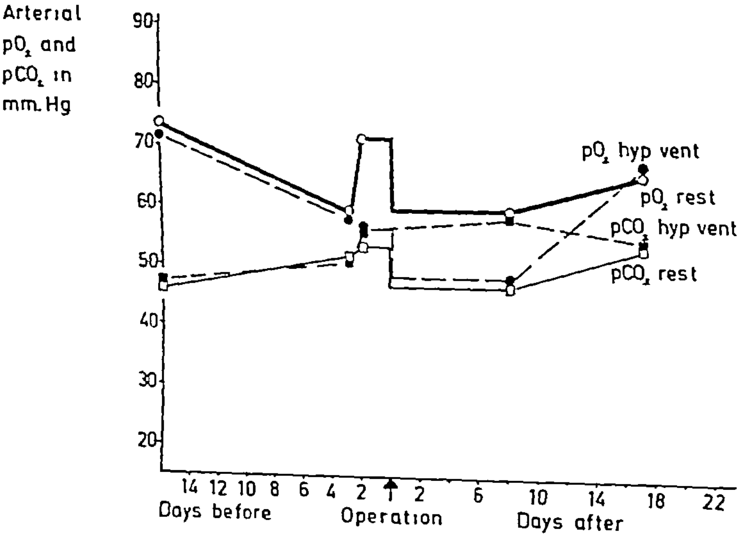

Fig 9 (Case 14)

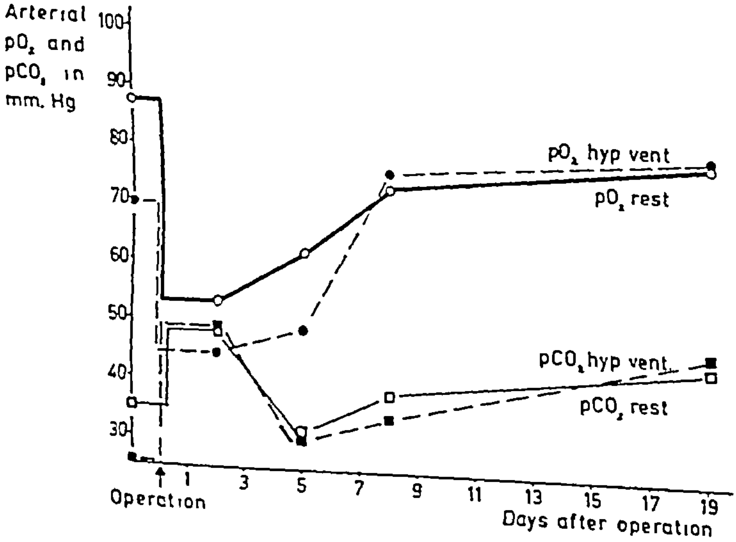

Fig 10 (Case 15)

Case 15 — A 27 year old man had a resection of the apical segment of the right upper lobe plus decortication and removal of the posterior ends of ribs two to five The preoperative arterial oxygen tension value was not reached after nineteen days (Fig 10)

Case 16—A 64 year old man had a resection of the apical segment of the right upper lobe and of the posterior ends of ribs two to six. He had normal preoperative values but a pronounced decrease of the arterial oxygen tension after the operation (Fig 11). A normal response to hyperventilation was found.

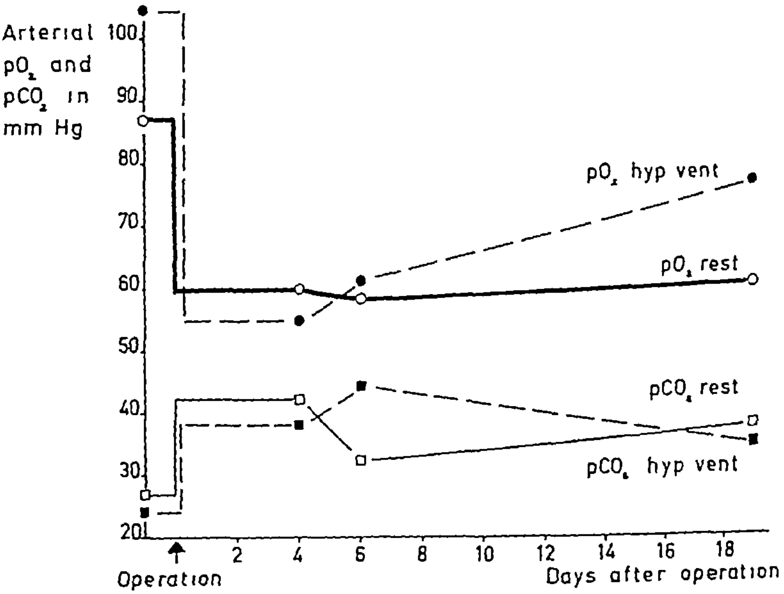

Fig 11 (Case 16)

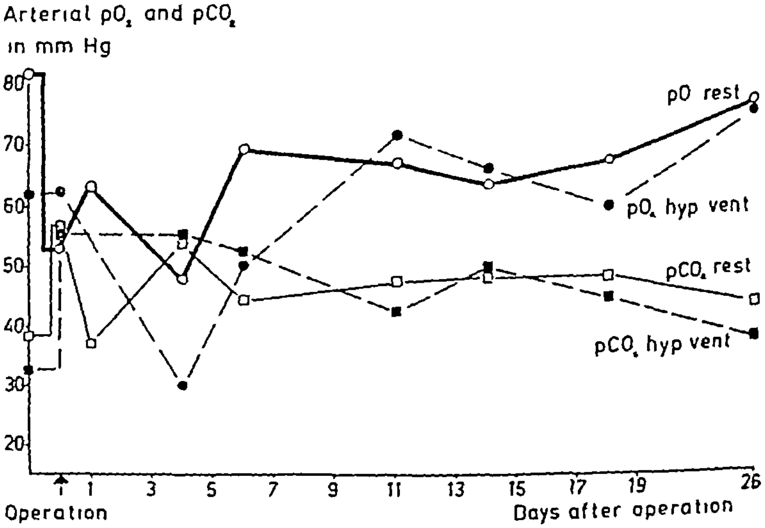

Fig 12 (Case 17)—A 25 year old man had a right 5 rib thoracoplasty with an apicolysis performed

Conclusion—It has been observed that if a thoracoplasty is performed at the same time as a resection a prolonged decrease in the arterial oxygen tension is encountered

VI *Thoracoplasty* —

Case 17 —A 25 year old man had had bilateral pneumothorax. A five rib thoracoplasty with apicolysis on the right side was performed Maximum breathing capacity was 116 L per minute Bronchospirometry showed 70 per cent oxygen uptake on the right side The arterial oxygen tension did approach the preoperative value after twenty six days (Fig 12) Fig 13, *A* shows an x ray view of the patient before operation Fig 13, *B* is an x ray view eleven days after operation showing a hematoma in the apicolysis space with a compression atelectasis Twenty three days after the operation the hematoma had been absorbed and the lung aerated (Fig 13, *C*)

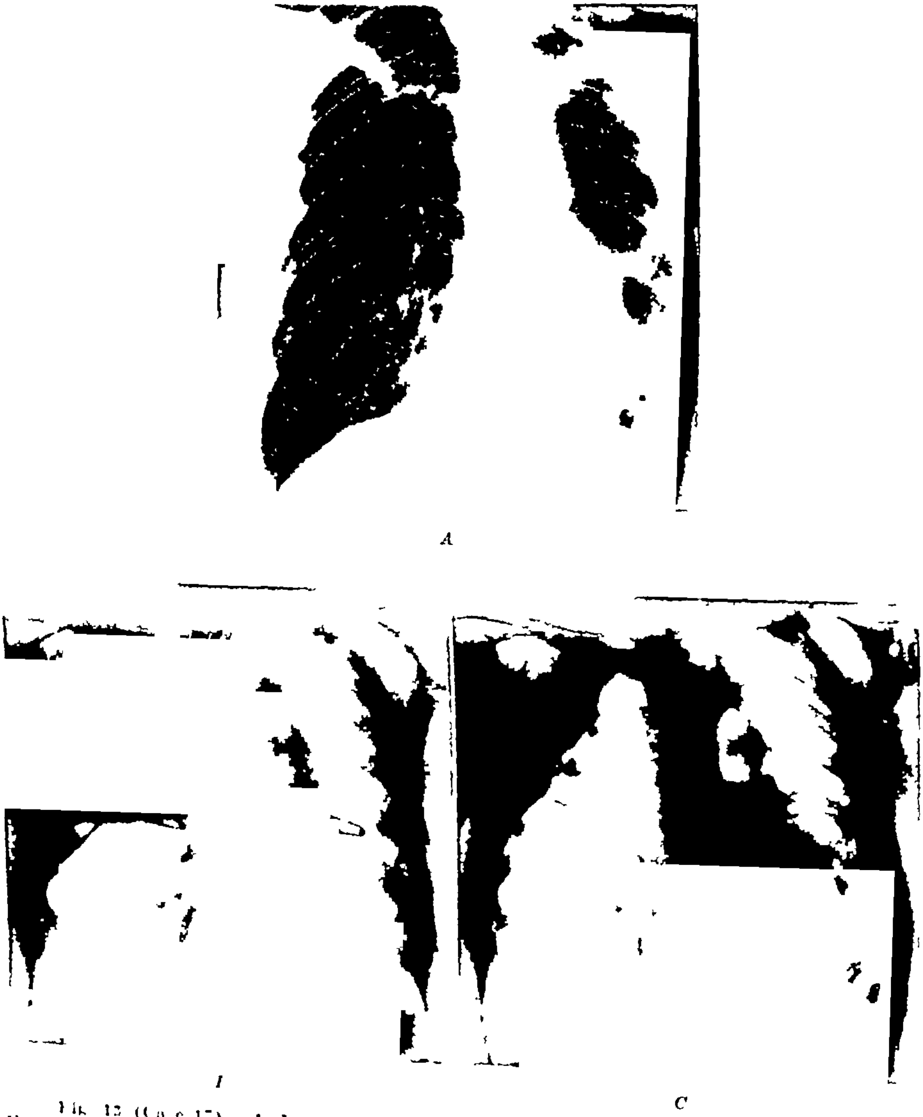

Fig 13 (Case 17) —*A* X ray view of the chest before operation *B* Roentgenogram of the chest eleven days after operation Hematoma in the apicolysis space *C* Roentgenogram of the chest twenty three days after operation the hematoma has been absorbed

Conclusion.—In this case of a five-rib thoracoplasty with apicolysis, a considerable decrease in the arterial oxygen tension was found during the postoperative period. Only after twenty-six days did the arterial oxygen tension begin to approach the preoperative level. Pain, paradoxical movements of the chest wall, and compression atelectasis, all contributed to the decrease in arterial oxygen tension. After about one month when the perfusion of nonventilated areas had diminished and ventilation had improved the normal values were first approached.

DISCUSSION

After all thoracic operations a decrease in the arterial oxygen tension has been found. The measurement of arterial carbon dioxide tension during the postoperative period has shown significant changes only in those patients with advanced disease who had preoperative retention of carbon dioxide. In this group it may be of value to detect the increased carbon dioxide tension early when a tracheotomy may be performed. This will diminish the dead space by approximately 100 ml., thereby improving the alveolar ventilation. In three cases of ventilatory insufficiency, arterial carbon dioxide tensions of 95.6, 117, and 124.5 mm Hg, respectively, were reached. In one of these patients the pCO_2 dropped 35 mm Hg after the tracheotomy, but all 3 patients died. The samples taken during voluntary hyperventilation have merely shown that it usually takes at least two weeks after the operation before the patients can increase the arterial oxygen tension during hyperventilation.

A decreased arterial oxygen tension the first few days following surgery has been found in pneumonectomies as well as in resections of lobes and segments with and without thoracoplasties. This immediate decrease in arterial oxygen tension is due to impaired ventilation. Pain, paradoxical movements of the chest wall, and atelectasis are all factors causing an impaired ventilation. In cases of pneumonectomy usually no atelectasis is present. In cases with simultaneous thoracoplasty, however, atelectasis, and paradoxical movements of the chest wall may be significant enough to cause a prolonged decrease in the arterial oxygen tension. From a functional point of view we therefore follow the policy of performing a first stage thoracoplasty with removal of the third to fifth upper ribs with apicolysis to the aortic arch or hemiazygos vein, respectively, in cases where lung tissue corresponding to a lobe or more is going to be resected. Then the resection is performed after two to three months.

There is however in many cases a need to diminish the thorax at the time of resection. After resection of a lower lobe we have done an extrapleural plastic plombage over the apex to dislocate the upper lobe down to the diaphragm in order to obtain the best possible ventilation. In most cases where the thoracic cavity is diminished I (Bjork) now use a thoracoplasty with resection of a small segment of the posterior ends of ribs two to five, two to six, or two to seven according to the amount of lung tissue resected. Small drill holes are made in the posterior ends of these ribs. Then drill holes are made as far back as possible in the uppermost rib which is not resected

Heavy stainless steel sutures through the holes will fix the posterior ends of the divided ribs which are bent in their cartilages to the uppermost intact rib and make a stable roof The first rib is either left in place or divided in front and at the back and sutured to the fifth transverse process An apicolysis is performed In this way we hope to prevent the paradoxical movement of the chest wall Furthermore with this method a thoracoplasty of a desired size can be obtained and will remain fixed The earlier tailoring thoracoplasty was usually found to be much smaller than expected when re-examined one year after the operation

SUMMARY

In thirty two patients with different degrees of pulmonary reserve pre- and postoperative studies of the arterial oxygen and carbon dioxide tension have been made

1 After pneumonectomy a decreased arterial oxygen tension was found for one week whether the resection was done under an old thoracoplasty (no paradoxical mediastinal movements) or not

2 In patients where a resection of lobes and segments under a thoracoplasty was performed the preoperative arterial oxygen tension was reached within two weeks in nine of sixteen cases

3 In a patient with a thoracoplasty and apicolysis a prolonged period of decreased arterial oxygen tension was found The paradoxical movements of the chest wall in combination with some atelectasis are thought to be the main source of this finding

4 If a resection of lobes and segments was performed at the same operation as a thoracoplasty a prolonged impairment of the arterial oxygen tension was found To exclude the paradoxical movement of the chest wall a thoracoplasty is now performed in which the ribs are fixed to the uppermost intact rib by sutures through drill holes

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CARBON DIOXIDE IN ANESTHETIC ATMOSPHERES AS MEASURED BY THE LISTON-BECKER (INFRARED ABSORPTION) GAS ANALYZER

Preliminary Report

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As "OPEN" thoracic procedures become more and more common the attention of anesthesiologists, thoracic surgeons, and research workers has been focused on the problem of adequate ventilation of the lungs of patients during the administration of anesthetic agents. Investigation of the problem has shown that some anesthetic techniques, most anesthetic agents[1-3] and some positions of the patient[4] necessary for the surgeon to accomplish his task interfere with adequate ventilation. This causes hypoxia and/or hypercarbia with consequent upset of the acid-base balance of the body which is reflected in the blood pH and pCO_2.

The alert anesthesiologist has many signs upon which he depends to guide him in preventing serious damage to his patient due to hypoxia. However, it has been shown by Comroe and Botelho[5] that groups of competent observers have been unable to recognize hypoxia in an anesthetized patient until the blood oxygen saturation drops to *70 per cent or below.*

The patient who has excessive accumulation of carbon dioxide in the body during the administration of an anesthetic does not have a sign as obvious as cyanosis to warn us. Blood pressure elevation, variations in the pulse, changes in the respiration and, of course, muscle twitching occur relatively late. Recent studies made using the mass spectrometer by Buckley and by Miller with their respective co-workers[6] have shown that with common anesthetic techniques allowing the patient to breathe spontaneously and unassisted carbon dioxide is retained in the patient more than the anesthesiologist realizes or would allow if he were able to judge by clinical signs. Admittedly, the mass spectrometer is bulky, highly technical to operate, and far beyond the cost most hospitals or anesthesiologists could afford.[7]

Recently Bardeen[8] has been working with a small inexpensive carbon dioxide analyzer for testing anesthetic mixtures. This analyzer requires a large sampling volume (500 to 700 ml.) which limits its continuous use, especially in closed anesthesia systems.

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'Open thoracic procedures constitute 95 per cent of the major operations in this hospital In an effort to determine the best means of administering anesthetics for this type of operative procedure it became apparent that some practical means of determining the variations in the patient's acid-base balance during the course of the operation was desirable For this purpose we have been using the Liston-Becker Gas Analyzer (infrared absorption) to measure the carbon dioxide in the respired atmosphere of the patients Efforts were made to determine the best method of sampling in order to reflect accurately the changes in acid base balance in the patients blood as they may occur

METHOD

This paper deals with the first forty cases and some of the difficulties encountered The patients were all given a dose of 0 3 mg of scopolamine one hour before induction of anesthesia Anesthesia was begun with 300 to 500 mg of Pentothal Sodium and 18 to 24 mg of tubocurarine After a short period of breathing (or inflating the lungs) with 100 per cent oxygen a cuffed endotracheal tube or Carlen double lumen catheter was put in place Maintenance of anesthesia was with a flow of 3 5 L per minute of nitrous oxide and 1 5 L per minute of oxygen with a to and fro canister in place Assisted respiration was used as soon as the patient was turned to the lateral position for the surgical procedure Controlled and/or artificial respiration were used while the pleura was open and further barbiturate or relaxant drug was used as needed

The Liston Becker Gas Analyzer (infrared absorption) (Fig 1) consists of two parts the "pick-up" and the control units The "pick-up" unit is sealed and may be "pressured" up to five pounds air pressure to make it safe for use with explosive anesthetic mixtures This unit must be located close to the patient's head A bracket may be made to fit any ordinary operating table (Fig 1) The "pick up" unit has interchangeable sampling cells One measures the carbon dioxide as all of the anesthetic mixture passes through the cell either as it enters or leaves the face mask or endotracheal tube For our studies we have been using another type of cell the "nasal catheter cell" A small continuous sample is drawn from the anesthetic mixture by means of slight suction sufficient to obtain the maximum deflection of the recording unit The sample is obtained through a small catheter (Becton Dickinson No 4421 polyethylene tubing or a No 51 ureteral catheter) The tip of this catheter can be placed in any part of the anesthetic atmosphere from the bronchi to the breathing bag This method of sampling the anesthetic mixture provides more latitude in the different areas which may be checked and it is more adaptable to different anesthetic techniques

The control unit is connected to the "pick up" unit by a cable and may be placed at a safe distance outside the operating room if necessary when explosive mixtures are used The carbon dioxide in the sample causes a deflection of a milliampere meter hand which can be read directly or permanently recorded by means of an Esterline Angus recorder or any of the various

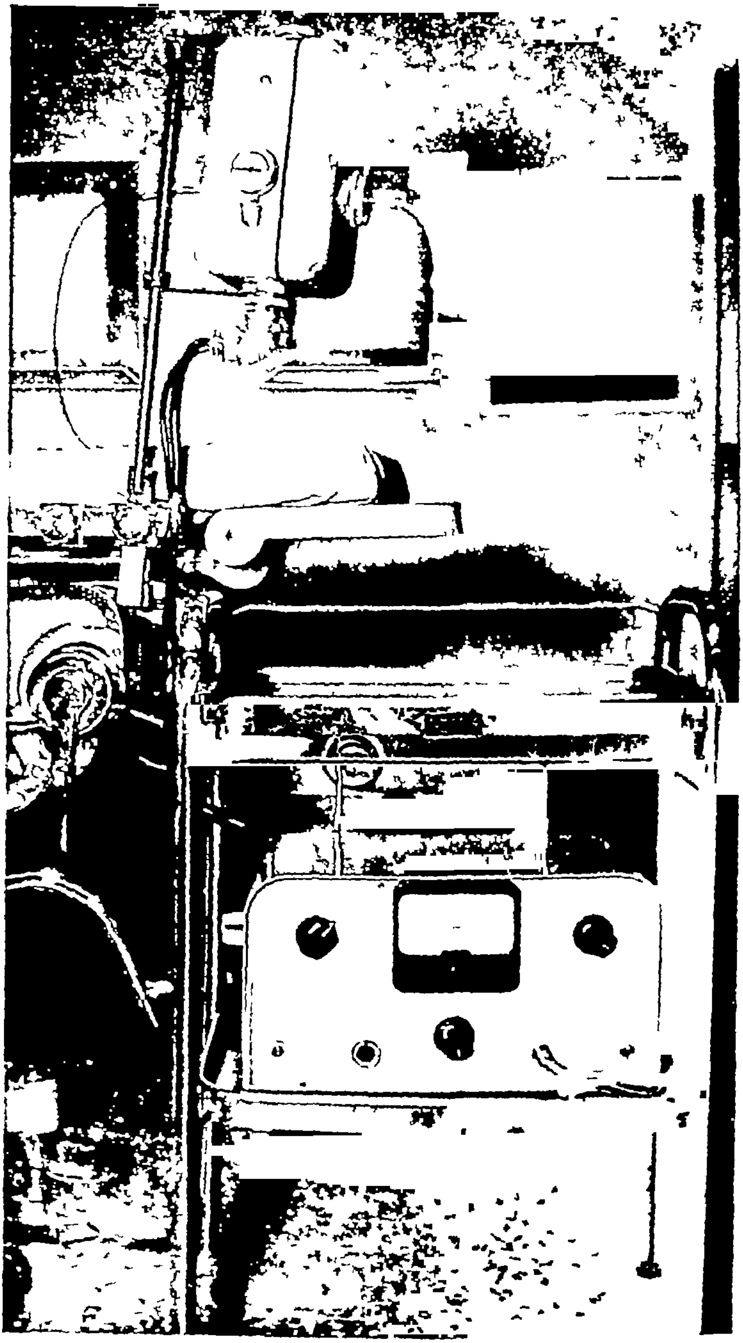

Fig. 1

direct writing electrocardiographs (such as those of the Sanborn variety) There is a "lag" of 0 1 second in the recording system Water *vapor* and anesthetic gases have no recordable effect on the readings[9]

It is necessary to turn the instrument on at least one hour before use, and it is more accurate and requires less frequent calibration if allowed to warm up overnight before using The range of the catheter cell is 0 to 15 per cent carbon dioxide The instrument is calibrated by the use of three known mixtures of carbon dioxide We have set air as the zero concentration of carbon dioxide and have three tanks of carbon-dioxide-oxygen (approximately 2 per cent, 5 per cent, and 10 per cent) for calibration The mixtures were previously analyzed by the Scholander method[10]

It is necessary to recheck the calibration with two of the known mixtures at least every hour If droplets of moisture, sputum, or other materials are sucked into the sampling cell it is necessary to clean it by drawing ether and/or carbon tetrachloride through it and permitting it to dry thoroughly

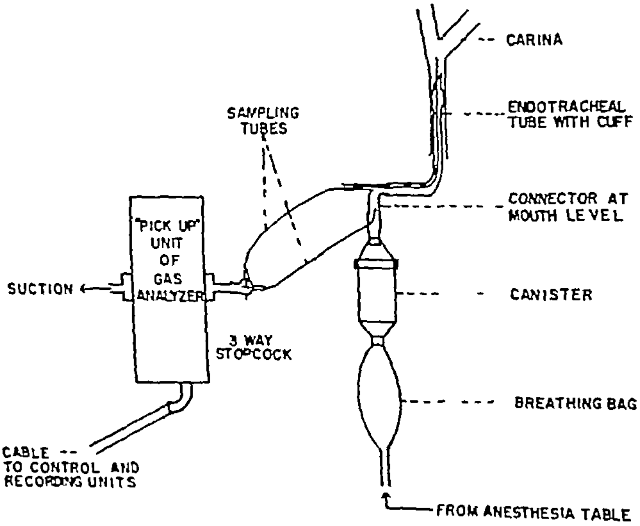

Fig 2

By means of a three way stopcock (Fig 2) and two sampling catheters, tidal samples could be drawn from two areas for comparison, within the space of one or two respirations

The blood samples were drawn from the pulmonary vein or occasionally, when the thorax was not open or the surgeon too busy, from a peripheral artery The whole blood carbon dioxide content was determined by the Van Slyke manometric method The whole blood pH was determined by the glass electrode pH meter kept at a constant temperature of 37° C Some of the gas samples were drawn through the infrared sampling cell into gas sampling tubes and these samples were analyzed by the Scholander method to check the accuracy of the instrument These analyses correlated with the readings on the gas analyzer within 0 06 per cent

"Alveolar" gas samples were taken by clamping the rubber tubing at the junction of the endotracheal tube connector and the to and fro canister thus diminishing mixing caused by the tidal flow of gas, and drawing the sample from the endotracheal tube, bronchi, and the more peripheral areas of the lung.

This "alveolar" reading is much more stable and accurate (as checked by blood analyses) (Table I) when all breathing effort can be temporarily stopped, as during controlled or artificial respiration.

RESULTS

The "alveolar" samples averaged about 33.9 per cent higher in carbon dioxide content than the tidal samples taken from the same area, and most of the time approximated more closely the variations in the *pH* and *p*CO of whole blood.

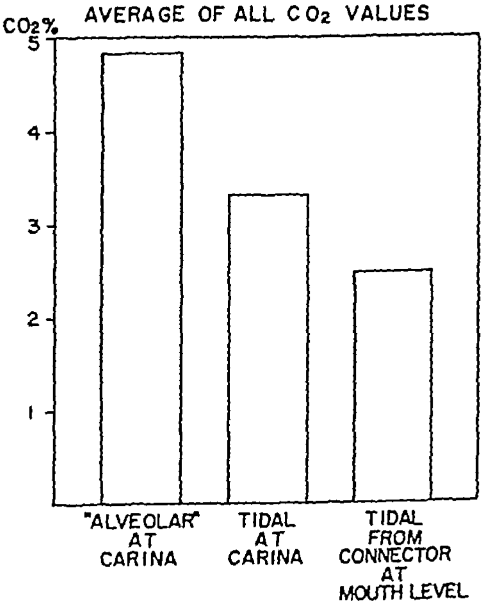

Fig. 3.

Tidal gas samples drawn from the endotracheal tube connector, as it projects from the mouth, average about 24.8 per cent less carbon dioxide than tidal samples drawn from the carinal area (Fig. 3).

DISCUSSION

Forty patients have been studied in this manner and it has been found that the tidal samples drawn from the region of the carina of the trachea are consistently higher (Table I) and at the height of the curve probably more nearly approach true alveolar air. Our "alveolar" samples more nearly reflect the actual concentration of carbon dioxide of whole blood than do samples drawn from "higher" parts of the pulmonary anesthesia system (Table II.)

It must be pointed out that our "alveolar" samples are "spot" samples. Fowler and Comroe[11] state that "a single 'spot' sample of expired gas is not necessarily an average or representative specimen of lung gas." Some of our "alveolar" samples showed a carbon dioxide content in excess of that of the carbon dioxide of arterial blood drawn from the pulmonary vein simultaneously with the "alveolar" sample. This would indicate that this type of sample is drawing gas from areas of lung that have recently been inadequately ventilated or to which the circulation has been impaired for a time. This could easily be due to mechanical factors such as retraction by the surgeon, or compression of the lung by packs, instruments or hands.

TABLE I

CASE NO.	AV. OF TIDAL SAMPLES CO_2 % TAKEN AT MOUTH LEVEL	AV. OF TIDAL SAMPLES CO_2 % TAKEN AT CARINAL LEVEL	AV. OF "ALVEOLAR" SAMPLES CO_2 % TAKEN AT CARINAL LEVEL
1	2.50	4.32	5.73
2	1.30	1.87	3.46
3	2.9	4.97	8.60
4	2.68	2.94	4.66
5	4.30	4.46	6.46
6	2.22	2.38	4.01
7	1.89	3.07	4.40
8	1.10	1.73	3.49
9	2.03	2.90	4.17
10	—	4.90	6.08
11	1.49	2.10	3.95
12	—	2.97	4.70
13	—	2.42	3.06
14	1.70	1.94	4.24
15	1.42	3.14	4.70
16	—	5.46	7.35
17	—	2.97	4.50
18	—	2.42	3.10
19	—	5.90	7.60
20	—	3.27	5.06
21	—	3.20	3.58
22	—	2.15	3.77
23	—	2.82	4.74
24	—	4.75	6.10
25	—	1.25	3.90
26	—	1.82	3.56
27	—	2.70	3.95
28	—	2.15	4.30
29	—	2.75	3.90
30	1.65	2.70	2.70
31	1.90	—	3.00
32	1.65	—	2.95
33	1.70	2.95	3.20
34	0.95	2.15	3.00
35	2.15	4.95	7.00
36	4.90	5.55	7.50
37	2.70	2.70	4.50
38	3.95	4.50	5.35
39	4.85	5.50	7.40
40	2.25	4.50	6.50

The readings of the carbon dioxide analyzer are very sensitive to mixing of the gas in the sampling area caused by inequalities in the tidal flow. Over-distention of the anesthetic breathing bag causing continuous positive pressure (even of a very mild degree, 1 to 3 cm. water pressure) causes lowering of the carbon dioxide reading. This indicates inadequate ventilation under these conditions. Wilhelm, Orth, and Waters[12] found that "a half filled bag simply hanging down from an endotracheal tube connection will create a condition of constant positive pressure in the system. Further pressure is created if a hand 'rests' on the bag, or the bag is fully distended." These findings emphasize the fact that the anesthesiologist must release all pressure from the breathing bag between inflations of the lung, not only to allow diastolic filling of the heart, as pointed out by Best and Taylor[13] but to allow free outflow of alveolar gases. Sudden compression of the lung during retraction by the surgeon or his assistants causes a high "peak" reading momentarily followed by a lower series of "peaks" if the retraction is maintained and other areas of the lung are not sufficiently ventilated to compensate for it. The tidal readings taken during the periods of inadequate ventilation may show a "low level" of carbon dioxide while an "alveolar" reading taken at this time especially after a more vigorous inflation, will indicate that carbon dioxide is "accumulating" in the blood and body. This "alveolar" reading cannot be taken as a true average due to the conditions pointed out above.

TABLE II

CASE NO.	BLOOD SAMPLE NO.	TIDAL SAMPLE AT MOUTH LEVEL CO IN MM. Hg TENS.	TIDAL SAMPLE AT CARINA CO_2 IN MM. Hg TENS.	"ALVEOLAR" SAMPLE AT CARINA CO_2 IN MM. Hg TENS.	CO_2 IN VOL. % OF WHOLE BLOOD	pH WHOLE BLOOD
14	1	8.88	18.87	29.60	48.19	7.52
	2	11.84	12.58	22.94	45.37	7.62
	3	8.88	14.06	25.90	44.56	7.53
	4	16.65	24.42	37.00	49.78	7.47
	5	14.06	21.22	34.06	46.75	7.40
15	1	—	38.48	42.92	54.30	7.35
	2	—	19.98	28.40	48.30	7.40
	3	10.36	10.36	23.31	43.90	7.57
	4	—	—	41.00	48.60	7.26
	5	—	—	34.69	45.00	7.37
24	1	—	—	60.40	48.21	7.38
	2	—	—	33.30	47.75	7.36
	3	—	—	37.00	45.42	7.43
	4	—	—	51.80	47.22	7.41
	5	—	34.78	42.92	49.00	7.52
26	1	—	14.06	31.82	56.54	7.26
	2	—	8.88	26.64	49.81	7.76
	3	—	11.84	23.68	44.00	7.40
	4	—	16.06	26.64	48.64	7.22
	5	—	15.42	26.64	49.77	7.78
	6	—	14.06	22.06	45.54	7.40

This instrument has been valuable to us in following the changes in the carbon dioxide content of the anesthetic atmosphere during periods of assisted artificial and controlled respiration while administering anesthetics for "open" thoracic procedures. Once the instrument is set up and calibrated it is relatively simple to place the sampling catheters and a continuous record can be taken. It is necessary to be vigilant in not allowing secretions or water droplets to be sucked into the sampling cell. This fact has probably been in strumental in causing the anesthesiologist to perform more frequent and effective tracheobronchial aspirations It has been noted that in this series of patients postoperatively there has been less than the usual amount of secretions and consequently less atelectasis

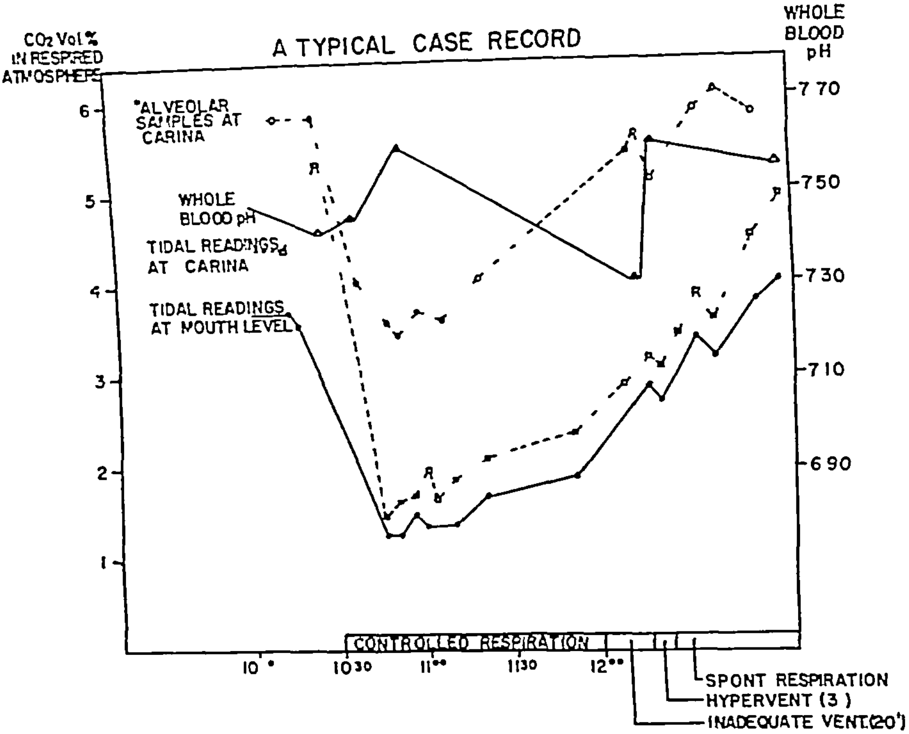

Fig 4

The curves of the carbon dioxide values and the blood pH values are inscribed graphically follow a pattern as shown in Fig 4 It will be noted that tidal values of carbon dioxide are sufficient to follow the *trend* of the whole blood pH and are preferred for routine use giving a good indication of changes in acid base balance The tidal readings at the mouth level are much easier to control due to less accumulation of secretions in this area However variations in mixing due to a distended breathing bag or to inadequate relaxation of the anesthesiologist's hand on the bag may cause errors in samples from this area

SUMMARY

1 A method of sampling anesthetic atmospheres and recording the variations in carbon dioxide content has been described

2 Forty cases have been studied to determine the variations in the carbon dioxide content when samples are drawn from different areas in the "pulmonary-anesthesia system"

3 Some causes of error are noted

The writers wish to express great appreciation to Mr Howard Rasmussen for valuable technical assistance and to the operating room personnel who have aided in many ways

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THYMIC CYSTS

A REVIEW OF THE LITERATURE AND REPORT OF TWO CASES

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INTRODUCTION

ALTHOUGH both the neck and the mediastinum are fairly common sites for cystic lesions of various types, cysts arising in the thymus gland are encountered most infrequently. Virtually all cysts of thymic origin reported in the early literature were found in syphilitic infants and were identified exclusively at necropsy. Thymic cysts due to syphilis have rarely been described during the present century. However, within the last decade a different variety of thymic cyst has been observed, and lesions of this type have been resected from both the neck and the mediastinum. Excision of tumors of the thymus gland has become commonplace in recent years and large series of cases treated in this manner have been reported by Seybold and his associates,[31] Blalock[illegible] and others[1, illegible, 21] yet only a few nonsyphilitic thymic cysts have been recorded in the literature.

Blades[4] and Laipply[illegible] in extensive reports of mediastinal tumors and cysts do not mention this lesion. The rarity of cysts of the thymus is attested by the fact that the literature contains reports of only eight which have been resected (Table I). Of these, four were removed from the neck, two from the mediastinum, and two by a combined cervical and mediastinal approach. None of these eight patients was syphilitic. The purpose of this report is to review the literature concerning thymic cysts and to record two such lesions which were excised.

HISTORICAL REVIEW

Lieutaud described suppurative changes in the thymus, in 1832, and he noted other changes due to syphilis during post-mortem examination of the two young male adults in whom the lesions were found. However, he related the alterations in the thymus to the caseous pulmonary tuberculosis present in each patient. Dubois, in 1850, described cystic alteration of the thymus in three newborn infants who died of congenital syphilis. He believed these cysts to be due to syphilitic suppuration. He stated that the changes were pathognomonic of syphilis and suggested that in Lieutaud's cases the alterations were due to syphilis rather than tuberculosis. Many authors[illegible] subsequently described cystic changes in the thymus. Most of these early reports appeared in the European literature and all the studies were made from

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The opinions or assertions contained herein are the private ones of the authors and are not to be construed as official or reflecting the views of the Navy Department or of the naval service at large.

Received for publication Aug. [illegible]

TABLE I BENIGN NONSYPHILITIC THYMIC CYSTS

AUTHOR	DATE	AGE	SEX	LOCATION	SIZE	WEIGHT	DIAGNOSIS	LINING	CONTENTS
Soupault[31]	1897	18 yr	F	Mediastinal	6 × 13 cm	69 Gm	Necropsy	Tall cylindric cells lining often irregular	Mucoid material, desquamated cells
Westenryk[39]	1900	51 yr	F	Mediastinal	"Walnut size"		Necropsy	Ciliated columnar epithelium	Multilocular, milky fluid
Pollosson and Piery[28]	1901	1½ yr	M	Cervical	"Fist size"		Excision (partial) and necropsy	Flat pavement cells	Multilocular with brown fluid
Pezzoller[27]	1929	5 yr	F	Cervical and mediastinal	1 cm		Excision (partial)	Cuboidal and cylindric cells	Serous material of brownish color containing granular and cellular debris
Fridjohn[11]	1944	12 hr	F		"As large as a walnut"		Necropsy	No microscopic examination	Thick glairy fluid, unilocular
Speer[35]	1938	25 yr	M	Mediastinal	7 × 5 × 13 cm	16 Gm	Necropsy	Simple and pseudostratified columnar epithelium, some ciliated, some areas flattened nonciliated cells	Granular and vacuolated material, multilocular
Kopac[14]	1939	30 yr	F	Mediastinal	"Like bunch of grapes"	60 Gm	Necropsy	Flat epithelium-like cells, cubic and cylindric forms seen	Clear red liquid multilocular

*Case reported in article.

Hyde, Sellers and Owen[17]	1939	5 yr	M	Cervical	7 x 5.5 x 12 cm		Excision	Pavement cells	Thick yellowish brown liquid containing cholesterol crystals, multilocular
Bradford, Mahon and Grow[3]	1947	22 yr	M	Mediastinal	One lobe 14 x 2.5 x 5 cm, other lobe 12 x 5 x 7 cm	71 Gm	Excision	Appeared to be persistence of epithelial ramifying strands of fetal thymus, cystic distention occurred in these	Multilocular
Smart[35]	1947	54 yr	F	Cervical and mediastinal	8 x 5 x 5 cm		Excision	Flat nonciliated cells	Straw colored fluid, unilocular
Crellin, Pugh and Janton[5]	1950	10 yr	F	Mediastinal	11 cm		Excision	Thick layer of fibrous tissue containing cholesterol crystals, no epithelial lining	Thin sanguineous fluid and brick red amorphous material, unilocular
Heinz[13]	1950	6 yr	M	Cervical	?	?	Excision	Squamous epithelium	?
Weller	1950	1 yr	F	Cervical	10 x 7.5 x 15 cm		Excision	Flattened cells and stratified squamous epithelium	Cloudy, pale brown fluid, unilocular
Pearce and Rapoport[38] Case 1	1953	21 yr	M	Mediastinal	6 x 10 cm		Excision	Low columnar to transitional like epithelium	Chocolate brown thick fluid, multilocular cyst
Case 2	1953	25 yr	M	Mediastinal	7 x 15 x 25 cm		Excision	Cells which appear to be reticulum cells, areas where cells appear more related to epidermoid cells	Amber colored watery fluid, multilocular cyst

necropsy material. The reported cysts were universally attributed to syphilis of congenital origin. The gland in these cases was generally multicystic with the individual cysts varying in size from a few millimeters in diameter to almost walnut size."

In 1901, Polloson and Piery[illegible] reported the unsuccessful attempt at removal of a fist-sized mass in the right neck of a 1½ year old boy. The mass was partially removed by morcellation, but the patient died the day of operation.

Pezcoller[27] reported, in 1929, the partial excision of a combined cervical and mediastinal thymic cyst which presented as a mass in the suprasternal notch of a 5 year old girl. The base of the cyst passed behind the sternum into the mediastinum. The stalk was amputated and the operation discontinued because of hemorrhage. In 1939, Hyde, Sellers, and Owen[17] reported the first complete excision of cervical thymic cyst. The lesion presented as a soft round mass about the size and shape of an ordinary hen's egg just below the angle of the right jaw anterior to the sternocleidomastoid muscle.

The first reports of a mediastinal thymic cyst to be excised at thoracotomy appeared simultaneously in the American and British literature in October 1947. On Aug. 23, 1946, Bradford, Mahon, and Grow[3] removed a mediastinal thymic cyst, and stated, "We are presenting a thymic cyst in an adult which completely replaces the gland, is not due to syphilis, and is apparently the first cyst of its type and size to be removed successfully." On Sept. 26, 1946, Smart[33] removed a large anterior mediastinal thymic cyst. The patient sought attention because of 'tightness in the neck' of one year's duration. This symptom was aggravated by lying down. When the cyst could not be removed through the thoracic approach, a thyroid-type cervical incision was made to complete its removal. Crellin's[9] patient had an anterior mediastinal cyst which was lower in location than the others which have been reported. It presented as a radiopacity overlying the left ventricular configuration. Brown, opaque, moderately thick odorless fluid (125 c.c.) was recovered by aspiration prior to thoracotomy.

EMBRYOLOGY AND ANATOMY

The thymic primordium is an entodermal outgrowth of the third branchial pouch on each side of the midline; the fourth branchial pouch rarely gives rise to some thymic tissue. The lower ends of the third pharyngeal pouch and the detached cervical sinus become solid epithelial bars which unite during the eighth week, become attached to the pericardium, and gradually sink with the latter into the thorax. The primordium has a narrow cufflike lumen and a thick wall consisting of several layers of cylindrical epithelium. The epithelial bud proliferates irregularly so that the lumen normally disappears and anastomosing strands extend into the mesenchyme. The future lobules arise at the ends of these branches. By the end of the third month differentiation into a cortex and a medulla is apparent.[7]

The thymus is a bilobed gland normally situated in the anterior mediastinum. The two lobes are closely joined by connective tissue but are not fused. Each lobe is divided into a number of lobules of varying size. The gland con sists of a cortex and a medulla which are usually sharply differentiated by a zone of connective tissue called the Strandberg layer The cortical substance consists of densely packed masses of small cells which are histologically identical with small lymphocytes the so-called thymocytes Although the origin of the thymocytes has not been fully established, the preponderance of opinion is that they are lymphocytes which have migrated into the thymus As the medulla is approached these thymocytes diminish in number and they are very sparse in the medulla proper The latter consists predominantly of reticular cells similar to those found in the reticulum of the cortex These reticular cells are believed to be derived from the original epithelium and thus differ from most other reticular cells of the body The reticular cells are said to give rise to Hassall s corpuscles although the origin of these bodies has also been ascribed to atrophy of terminal blood vessels Degeneration and hyalinization are common in Hassall s corpuscles they sometimes become calcified

Thymic cysts which appear to be related to branchial and cervical cysts, are usually derived from a remnant of the third branchial pouch They may be located in any position along a line extending from the angle of the jaw medially to the midline of the neck thence descending into the anterior mediastinum to the pericardium as far distant as the diaphragm These lesions are most frequently detected as an anterior mediastinal mass on chest roentgenograms or as a palpable mass above the suprasternal notch A cervical mass especially if in the suprasternal notch may represent an extension of a mediastinal thymic cyst or it may be a solitary lesion confined to the neck

ETIOLOGY AND CLASSIFICATION

Dubois[7] considered that the presence of pus in the thymus had resulted from a syphilitic inflammation of that organ Simmonds[32] found great numbers of spirochetes in these cavities Chiari[4] felt that these were not abscesses but epithelium lined cysts filled with small thymus cells He observed that such cysts may also be found in children without evidence of syphilis Eberle[5] described cysts filled with pus and believed them to be from rests of the thymic duct lumen arrested during fetal development as a consequence of syphilis Tuve ascribed their origin to medullary necrosis Kopac[19] noting the age of his patient (56 years) and the unilateral alterations rejected the concept of a developmental arrest and ascribed the etiology in his case as due to medullary necrosis with reticular cell lining of the necrotic area resulting in the formation of a cyst

Heinz[2] in his discussion of lymphoepithelial cysts of the neck defined a branchial cyst as one lined by epithelium and surrounded by a well developed lymphoid stroma He believes that branchial cysts are probably derived from a remnant of the thymic duct and suggests that these cysts be called 'lateral lymphoepithelial cysts in preference to the term branchial cyst a term which he considers misleading Hicks[3] has recently observed that thymus tissue is said to occur occasionally in branchial cysts However in 100 branchial cysts reviewed for histologic characteristics in his laboratory no unequivo cal thymus tissue was seen Heinz reported the case involving a 6 year old boy with a palpable mass in the posterior triangle of the neck at the angle of the jaw The contents of the cyst were not stated Papillary projections within the cyst were covered by a stratified squamous epithelium There was an abundant lymphoid stroma about this, which contained Hassall's corpuscles Heinz, however, did not use the term thymic cyst in his description He is of the opinion that these lateral lymphoepithelial cysts are akin to the solid lymphadenomas of the neck, which occasionally do contain squamous epithelium Heuer and Andrus[14] recorded an anterior mediastinal cyst which showed a configuration on roentgenogram similar to Case 1 reported here They described it as a "cyst originating in a branchial rest"

Persistent tubular remnants of the third branchial pouch (thymic duct) are thought to undergo hemorrhage or fluid accumulation causing enlargement of the thymus gland Previously normal chest roentgenograms in several of these cases attest to this enlargement The cause of fluid accumulation or hemorrhage has not been established Trauma seems unlikely and infection is not borne out by the clinical course or by histologic examination of the excised gland

Crotti[6] described (1) the ciliated cyst, which may be derived from several processes within the gland, and (2) the congenital syphilitic cyst Elsewhere in his text he mentioned "hemorrhagic cysts" due to rupture of terminal blood vessels into a preformed epithelium-lined cavity, a remnant of the thymic duct and almost always found in congenital syphilis

Ewing[10] states that these cysts may be derived from (1) the epithelial canals of the embryonal thymus which persist and form one or several small or large cysts, and especially frequent in syphilitic patients, (2) dermoid cysts, (3) invasion and distention of Hassall's corpuscles, and (4) cystic lymphangioma

Speer[30] observed that thymic cysts may be of five types, developing (1) from embryonal remnants of the thymopharyngeal ducts, the branchial clefts or the thymic tubules (2) from sequestration products in pathologic involutions of the gland (3) from degenerating Hassall's corpuscles, (4) from lymph vessels blood vessels, or connective tissue in various stages of thymic development hyperplasia or involution, and (5) from neoplastic processes in the lymphoid cytoreticular or connective tissues

We believe that thymic cysts may be divided logically into three groups (1) congenital (2) inflammatory and (3) neoplastic The nonneoplastic noninflammatory cysts of the thymus reported here are probably congenital in origin in that a congenital defect may have been present in the form of a patent thymic or thymopharyngeal duct persisting until such time as fluid or hemorrhagic distention occurred Why this happens is not known Cysts resulting from infection appear invariably to be due to syphilis Although rather common in the past thymic cysts of this etiology are now rarely encountered Cysts occurring in thymic neoplasms can probably be attributed to degeneration and necrosis of the tumor

CASE REPORTS

CASE 1—B C F, a 21 year old white man, was in good health until he developed a left lower lobe pneumonia in January, 1952 Chest roentgenograms revealed a pneumonic infiltration in the left lower lung field and a bilaterally widened superior mediastinal shadow (Fig 1) He recovered uneventfully from the respiratory infection, but the superior mediastinal shadow persisted There was no history to suggest either congenital or acquired syphilis

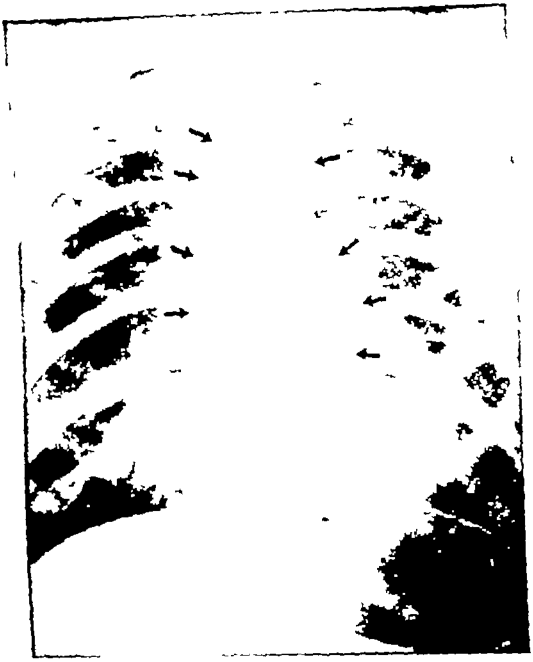


FIG 1—(Case 1) Posteroanterior roentgenogram demonstrating the mediastinal mass

Physical examination and laboratory studies were normal The Kahn test was negative The anterior mediastinal mass, which overlay both hilar regions, extended upward to the level of the sternal notch The mass could not be clearly delineated in the lateral view A chest film made in October, 1951 had also shown an abnormal right superior mediastinal shadow Considerable enlargement of the mass to the left during the intervening three months was seen Angiocardiographic studies did not demonstrate any opacification of the lesion Bronchoscopic examination showed the tracheobronchial tree to be normal in configuration with no evidence of bronchial compression Bronchograms established the presence of bilateral bronchiectasis with most marked involvement on the left On March 24 1952, a left thoracotomy was performed through a posterolateral incision A free pleural space was encountered The bronchiectatic left lower lobe was first resected

Attention was then directed to the mediastinal tumor It was found to be completely cystic in nature The presenting surface appeared to be roughly oval in shape and measured about 4 cm in diameter The mass presented over the left auricle and the phrenic nerve and its accompanying vessels coursed over the cyst at the junction of its middle and posterior thirds The phrenic nerve was adherent to the capsule The cyst overlay the ascending aorta and the aortic arch extending outward to the left to the point of take off of the subclavian artery (Fig 2) The pleura was stripped from the capsule with relative ease While the [illegible] was being dissected from the capsule of the mass the lesion was perforated and some [illegible] material extruded The cyst was found to extend medially crossing the ascending aorta and projecting into the right chest A necklike prolongation extended upward, coursing in a generally anterior direction so that at the sternal notch it lay between the innominate vein and the posterior surface of the sternum This necklike prolongation [illegible] into the neck about 2 5 cm above the superior margin of the manubrium The cyst was removed in toto through the thoracic approach

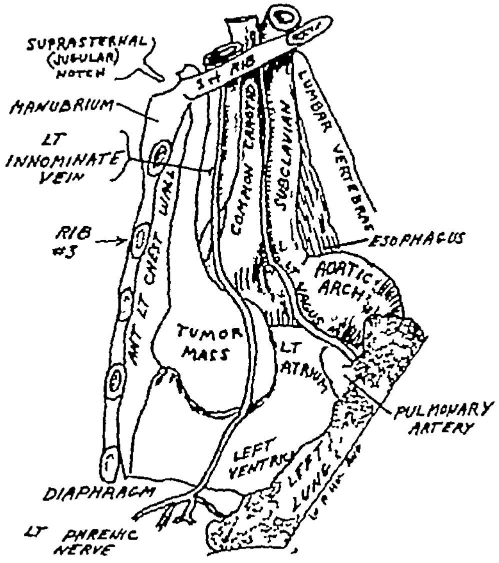


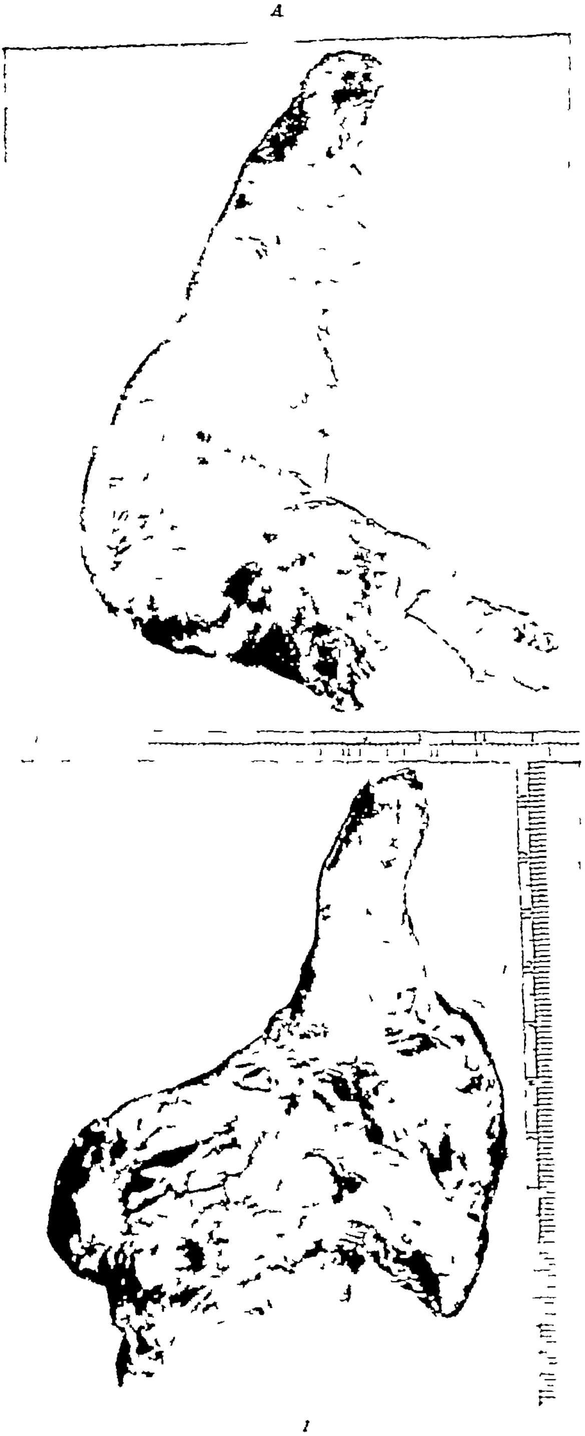
Fig 2—(Case 1) Diagrammatic sketch of the thymic cyst at left thoracotomy and its relationship to mediastinal structures

Pathologic Examination—The specimen consisted of a cystic mass which was roughly triangular in shape and measured 10 by 6 by 3 cm in size The outer surface was slightly lobulated, fairly smooth, and brown (Fig 3, 4) The cyst contained 15 c.c of chocolate brown thick fluid and revealed a shaggy, grayish brown trabeculated inner surface (Fig 3 B) Several flattened blood clots were adherent to the inner lining Closer examination showed numerous smaller cysts within the wall of the major cyst The thickness of the latter varied from 0 3 to 1 3 cm Although the specimen was multicystic, the smaller cysts probably communicated with the central large cyst inasmuch as the smaller cystic spaces were found to be devoid of fluid after the main cyst was drained

Microscopically the cyst and fibrous trabeculations were lined by low cuboidal or pavement epithelium (Fig 4) Medullary and cortical thymic tissue elements were immediately adjacent to this epithelial lining or separated from it by collagenous fibrous connective tissue of varying thickness Hassall's corpuscles were present and most of them were calcified Clotted blood and irregular or spherical masses of thymic medullary tissue were attached to the cyst lining or lay free in the lumen There were scattered foci of cholesterol clefts surrounded by foreign body giant cells

CASE 2—J S, a 26-year-old white man, was found to have an abnormal anterior mediastinal shadow on a routine chest roentgenogram (Fig 5) There was a convex density which projected to the right of the midline in the region of the ascending aorta extending from the level of the sixth to the eighth thoracic vertebrae The mass was not clearly visible on the lateral film The patient was asymptomatic There was no history suggestive of either congenital or acquired syphilis Physical examination and laboratory studies were within normal limits The Kahn test was negative

On Dec 30 1952, a right thoracotomy was performed through a posterolateral incision A free pleural space was encountered The tumor mass, which was roughly egg shaped



[illegible] thymic cyst. A Outer surface. B Cut surface. Note the trabeculation of the inner surface.

ured about 6 cm in the long or vertical axis and 4 cm in the short or transverse diameter I was situated anterior to the superior vena cava and in the anteroposterior direction ext from that point to the retrosternal area Its long axis was vertical Inferiorly it r the base of the heart and superiorly it extended to a point near the thoracic inlet (Fi 6

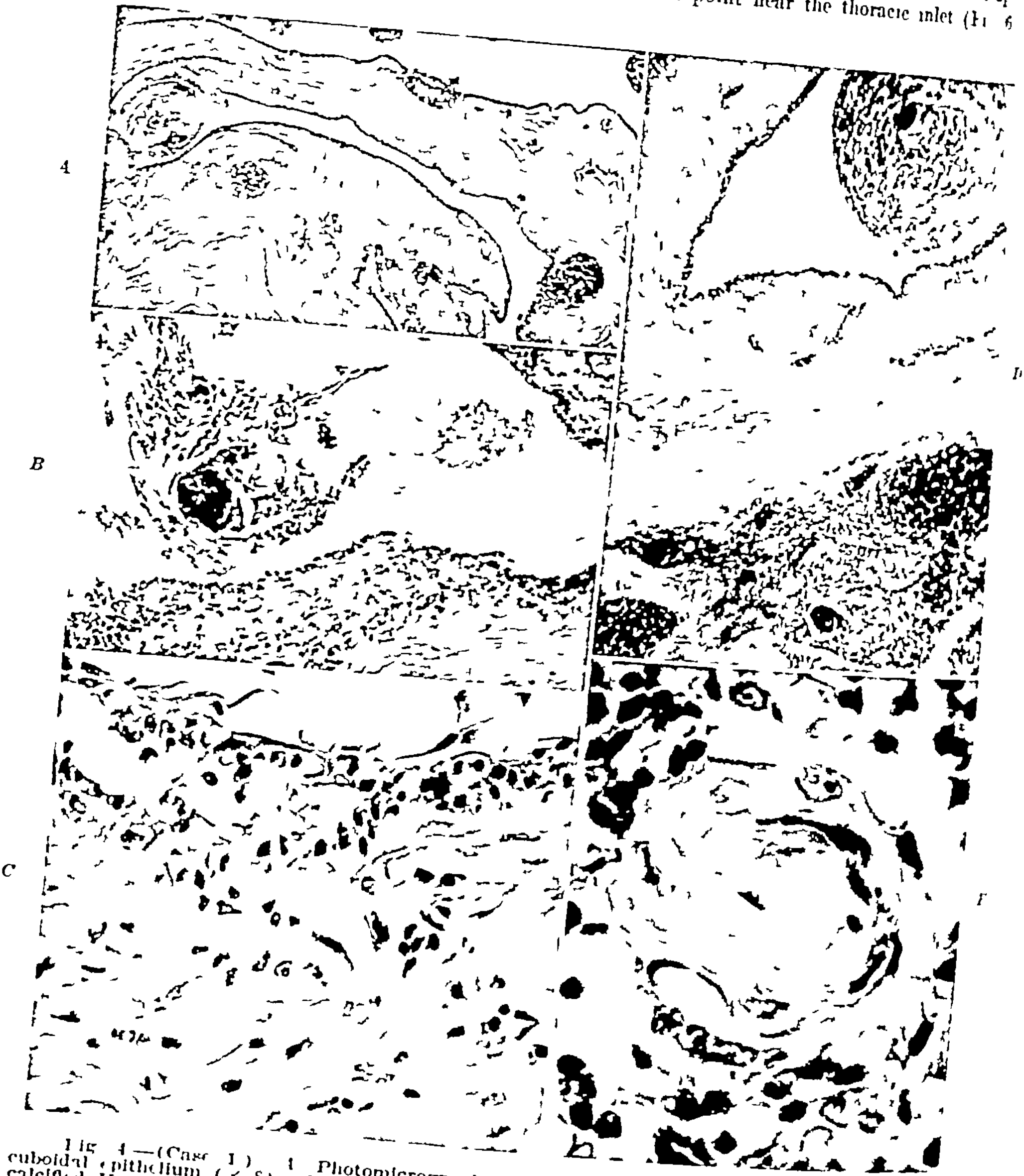


Fig 4—(Case 1) A Photomicrograph showing a fibrous trabecula covered by l cuboidal epithelium (×25) B Cyst containing a sequestrum of medullary tissue including a calcified Hassall's corpuscle (×70) C Higher magnification of cyst lining showing de qu mating pavement cells and cuboidal cells covering hyalinized fibrous connective tissue (×[illegible]) D Ramification of the cyst separated from thymic cortical substance (lower one third) by a broad band of fibrous connective tissue (×50) F High magnification of a Hassall's corpuscl (×[illegible])

The mass was largely cystic except for a small solid portion at the inferior pole The over lying pleura was not adherent to the tumor and stripped from it with ease At no point was it firmly adherent to the contiguous structures The lesion appeared well encapsulated and was shelled out and removed without difficulty

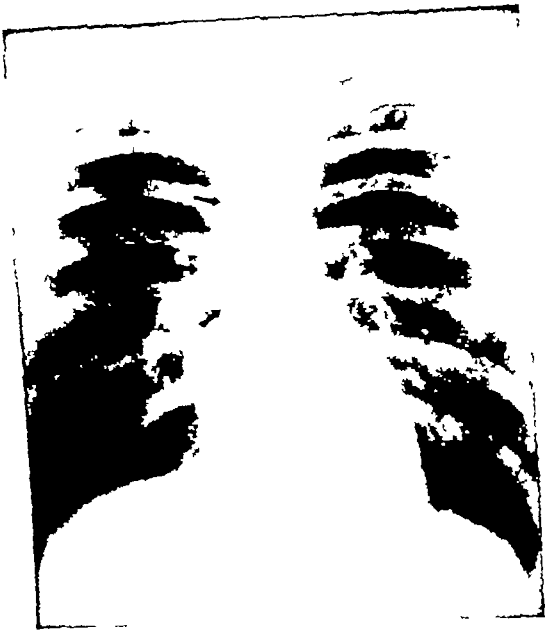


Fig. 5 —(Case [illegible]) Posteroanterior roentgenogram demonstrating the mediastinal mass

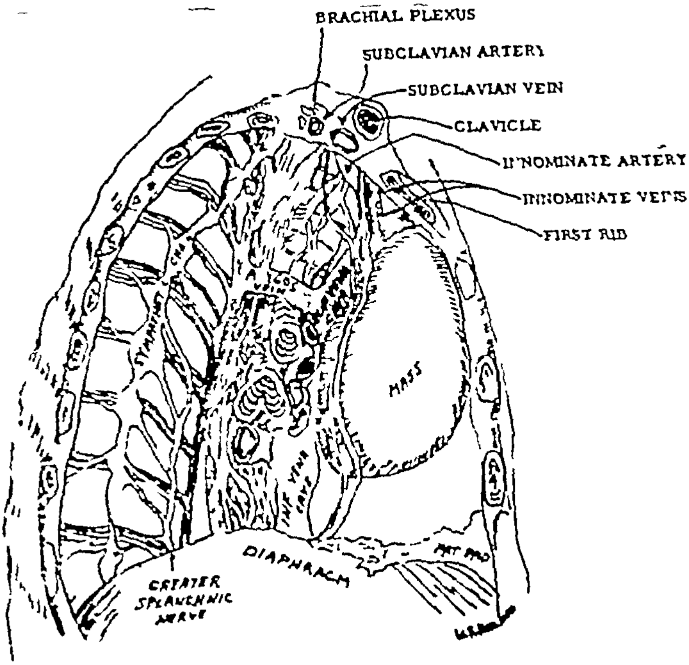


Fig. 6 —([illegible]) Diagrammatic sketch of the thymic cyst at right thoracotomy and its relationship to mediastinal structures

[illegible] Examination.—The specimen consisted of an oval-shaped cystic mass which [illegible] by 7 by 2.5 cm in size. The outer surface was smooth, lobulated and reddish [illegible] (Fig. 7 A). At the inferior pole the consistency was firmer, suggesting solid tissue. The cyst contained watery, amber colored fluid. The cyst wall varied in thickness from several millimeters in the upper portion to several centimeters at the lower pole. Smaller cysts were found within the solid portions and seemed to drain into the large central cavity. The inner surface of the cyst was shaggy and grayish red, with numerous trabeculations (Fig. 7, *B*).

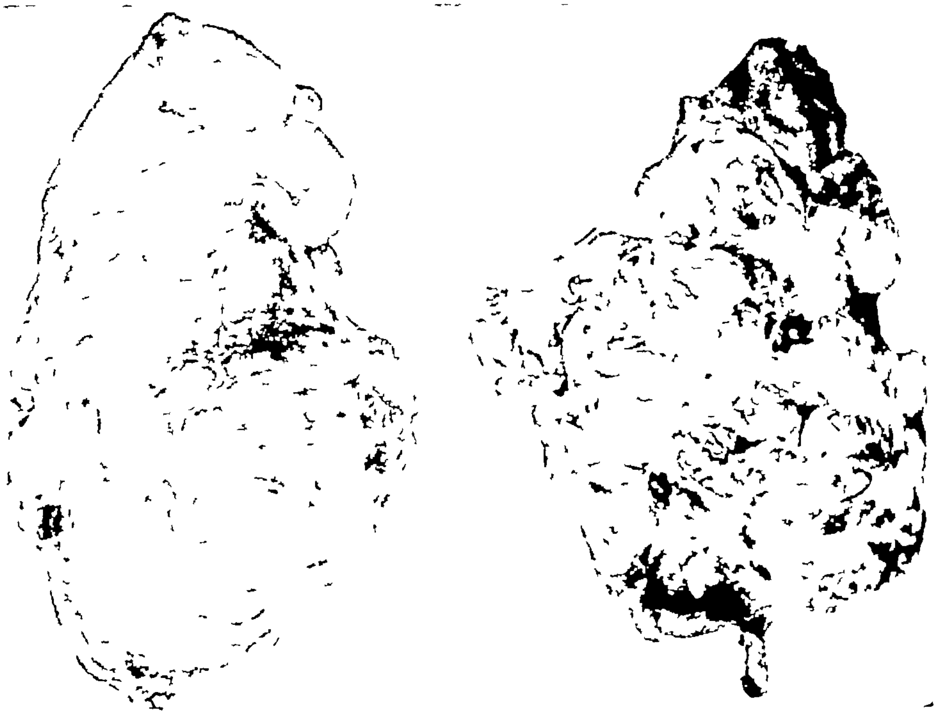


Fig. 7.—(Case 2.) Photograph of thymic cyst. *A*, Outer surface. *B*, Cut surface.

Microscopically, the large cyst and its communicating spaces were lined by low cuboidal epithelium or pavement cells. Remnants of medullary and cortical thymic tissue were recognizable in the wall, within the intracystic papillary projections, and in the fibrous trabeculae. Loose, irregularly shaped, or spherical bodies were found within the lumen. These were composed of reticulum cells admixed with thymocytes and inflammatory cells and appeared to represent sequestra of medullary tissue. A few small cystic spaces contained numerous cholesterol crystals.

Discussion of the Histologic Findings.—Examination of multiple sections demonstrated probable stages in the development of the cysts (*Fig. 10, A*). The smallest were situated in the center of a thymic lobule and their linings consisted of medullary reticulum (Fig. 10, *B* and *C*). As the cysts grew larger two changes became apparent. The medullary tissue was compressed and finally disappeared except for a thin layer of compressed reticulum cells which now appeared as pavement cells. The normally inconspicuous Strandberg connective tissue layer, which forms the corticomedullary boundary, underwent marked thickening by collagenous connective tissue (*Fig. 10, C*). The end result was a three-layered cyst wall consisting of an innermost thin layer of pavement cells, a broad connective tissue layer and a layer of compressed thymic cortical tissue.

[illegible] micrograph showing the cyst with several communicating [illegible] the lymph[illegible] of thymic cortex in the wall (×[illegible]). *B* Cyst lined by [illegible] thymic cortex. Note the papillary projection containing [illegible] Has[illegible] containing [illegible] (lower portion). A [illegible] in the upper portion (×28[illegible]). *D* Irregular [illegible] and showing a small calcified body beneath the [illegible]. The [illegible] spherical body is composed of an [illegible] and thymocytes.

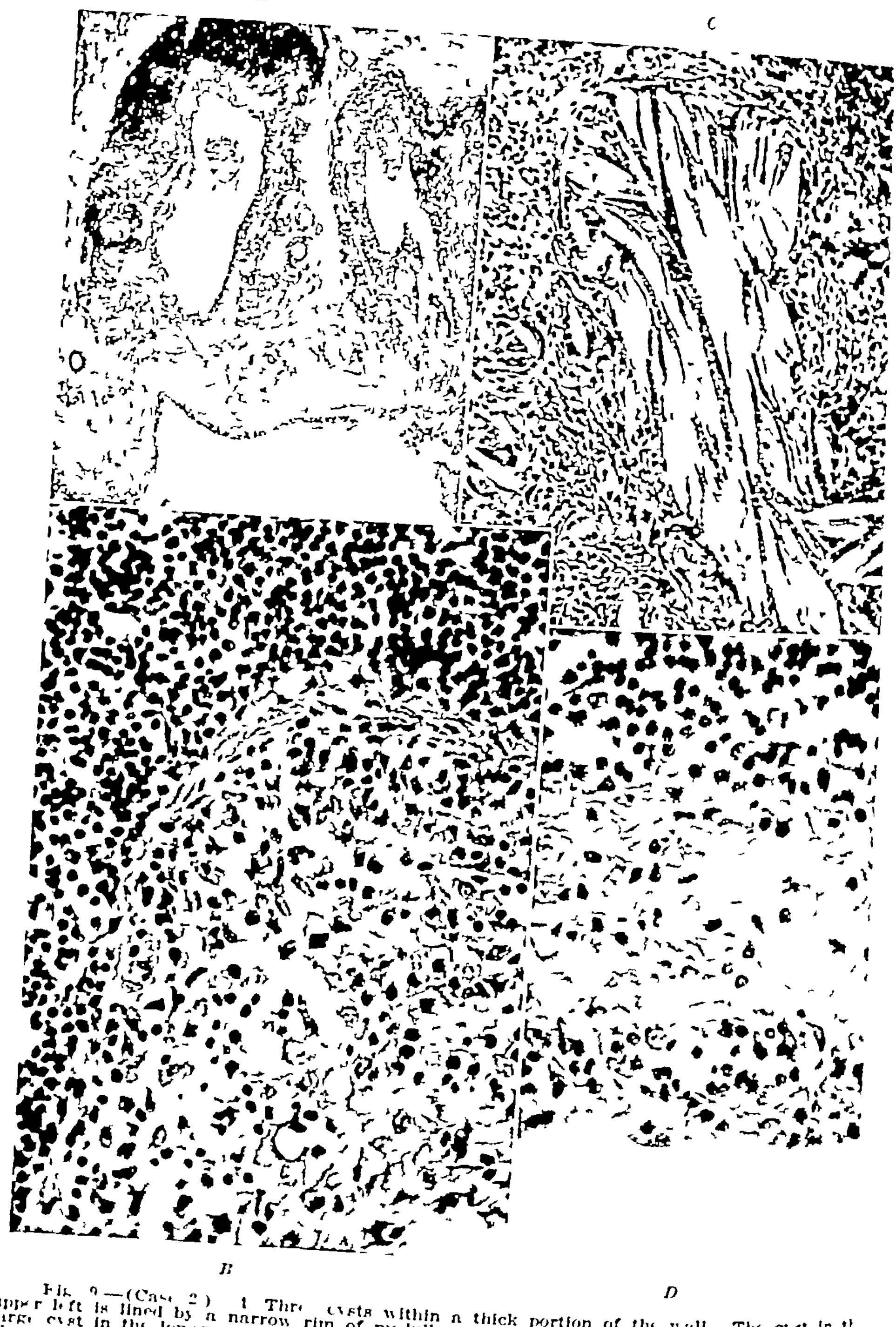
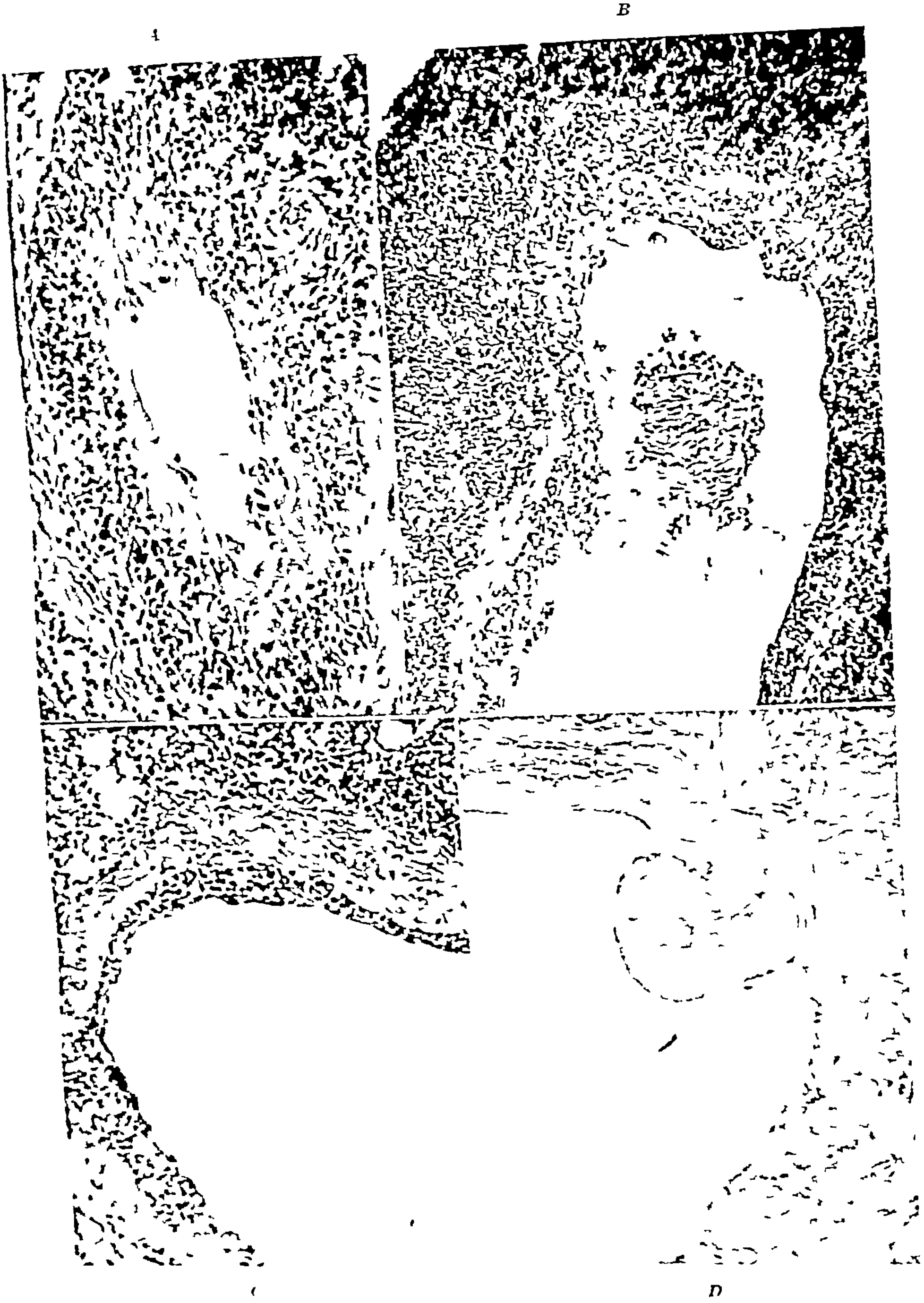


Fig. 9.—(Case 2.) *A*. Three cysts within a thick portion of the wall. The cyst in th upper left is lined by a narrow rim of medullary tissue and a broader zone of cortex. Th large cyst in the lower portion of the photograph has lost its reticulum cell and lymphocyti elements. (×25.) *B*. Higher magnification of the cyst in the upper left portion of Fig. 9 A. Note the separation of the thymic cortex with its abundant thymocytes from the less ce lular medulla by the connective tissue layer of Strandberg. Lining pavement cells are s in the lower right hand corner. (×300.) *C*. A focus of cholesterol spaces surrounded by scat tered foreign body giant cells. (×300.) *D*. Higher magnification of the cyst seen in the lowe portion of Fig. 9A. Four distinct layers from top to bottom consist of (1) thymocytes of cortex, (2) collagenous connective tissue, (3) remnants of medulla, and (4) thin layer of pav ment cells lining the lumen. (×200.)



[illegible] in cyst development. A, Early stage with small cyst within a thymic [illegible] (× 140). B, Large cyst with persistent medullary and cortical layers (× 70). C, Mid- [illegible] stage [illegible] Marked fibrous thickening of Strandberg layer separating [illegible] D, Final stage with only collagenous connective tissue lining the [illegible]

TREATMENT

The preoperative diagnosis of a thymic cyst is presumptive Any undiagnosed cervical or anterior mediastinal mass may represent such a lesion The presence of a mass that could be a cyst of the thymus is the indication for its removal The cyst should be completely excised This is usually accomplished either through a cervical or thoracic approach, dependent upon the location of the mass At times a combined approach may be required in order to accomplish complete removal of a thymic cyst which lies partly in the neck and partly in the mediastinum

SUMMARY

Two thymic cysts, which presented as anterior mediastinal masses on chest roentgenograms and were diagnosed by histologic examination following excision at thoracotomy, have been reported Eight additional thymic cysts excised through a cervical incision or at thoracotomy, or both, have been tabulated from the literature The literature pertinent to this subject has been reviewed

A simple classification of thymic cysts has been proposed (The thymic cysts which we have reported and collected were noninflammatory, nonneoplastic, and were probably of congenital origin) Thymic cysts become clinically manifest when fluid accumulation or hemorrhage occurs into a thymic duct or thymopharyngeal duct remnant The cause of this phenomenon has not been established

Thymic cysts present in the neck or anterior mediastinum and usually give rise to no symptoms They may be unilocular or multilocular The lining epithelium is characteristically cuboidal or pavement-type epithelium These cysts commonly contain fluid with fresh or old blood elements and cellular debris within their cavities

An accurate preoperative diagnosis of these lesions is usually impossible The treatment of choice is total excision

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ADDENDUM

Two additional thymic cysts have been resected since submission of manuscript

CASE 3—W J K, a 25 year old white man who complained of chest pain on deep inspiration was found on chest roentgenogram to have a large anterior mediastinal mass projecting into the left chest and occupying the thoracic inlet This was removed at left thoracotomy The specimen measured 12 by 8 3 by 5 5 cm and was rough and shaggy on the outer surface On section it appeared as a trabeculated pseudolobulated cyst with smooth lining and containing blood clots The lining was of squamous epithelium Hassall corpuscles were present in the wall of the cyst

CASE 4—C W N, a 33 year old white man was seized with sharp stabbing pain in the [illegible] and left [illegible] Chest roentgenogram revealed a large anterior mediastinal mass projecting into the right chest This was removed at right thoracotomy The specimen measured 12 cm in greatest diameter with a fibrous shaggy outer surface On sectioning it contained [illegible] clots and liquid bloody material within the prominent trabeculation The lining [illegible] epithelium A parathyroid gland was found on microscopic examination in [illegible] wall

THE RELATIONSHIP BETWEEN MEDIASTINAL LIPOMAS AND THE THYMUS

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A PATIENT was recently found at operation to have a mediastinal tumor containing thymic and fatty tissue. This unusual tumor aroused our interest because the possibility suggested itself that mediastinal lipomas may originate in the thymus, as a result of the infiltration of the organ with fat during its involution. A review of the literature of so-called lipothymomas (the tumor encountered in our patient was representative of this type) and lipomas of the mediastinum gave support for this hypothesis. It was noted that with few exceptions intrathoracic lipomas are located in the anterior mediastinum in front of the heart and great vessels. Many of the large lipomas, exceeding the bounds of the mediastinal compartment, were connected by a pedicle or a projection of tissue with the thymic area. Particularly significant was the finding of thymic tissue in some of these lipomas. It can be assumed therefore that mediastinal lipomas may be related to the thymus.

CASE REPORT

E. C., a 19 year old woman from Puerto Rico, was admitted to the Thoracic Surgical Service of Morrisania City Hospital on July 23, 1952, complaining of exertional chest pain of six months' duration. The pain was sharp, nonradiating, and localized to the second and third intercostal spaces to the right of the sternum. Five years previously a chest x-ray film taken after a seizure of pneumonia, had been interpreted as showing enlargement of the heart. The patient was advised to consult a cardiologist, which she did not do.

On April 10, 1952, she was admitted in labor to the Obstetrical Service of the Morrisania City Hospital. A chest roentgenogram at this time revealed a large mass in the anterior mediastinum to the right of the heart (Fig. 1). It was triangular in shape with the base resting on the diaphragm, the apex blending with the superior mediastinum. Noteworthy was the decreased density of the peripheral portion of the tumor in comparison to the central area. Following an uneventful delivery, the patient was discharged and advised to return after convalescence. On readmission to the hospital two months later the patient stated that shortness of breath had increased in severity.

Physical examination revealed a well-developed woman not in respiratory distress. Except for dullness and diminished breath sounds over the right chest anteriorly, no other physical abnormalities were found. Routine laboratory studies were within normal limits. Chest x-ray examinations revealed findings similar to those noted upon the first admission. A bronchoscopy was negative. Angiocardiographic studies* showed the mass to be unrelated to the heart and great vessels. From the radiographic appearance of the tumor a mediastinal lipoma was considered the most likely possibility.

On Sept. 24, 1952, the mediastinum was exposed through a right posterolateral incision. A large, well-encapsulated, lobulated mass was found in the anterior mediastinum adjacent to the heart. The mass was conical in shape with the base on the diaphragm and apex extending as a pedicle into the superior mediastinum. The tumor had the gross appearance of a lipoma. The mass was covered by mediastinal pleura and was easily mobilized from the

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From the Thoracic Surgical Service, Morrisania City Hospital.
Received for publication Oct. 26, 1953.

*Done by Dr. W. Rosenbluth.

diaphragm and pericardium. At the apex the pedicle could be traced anteriorly and medially to the superior vena cava into the thymic region behind the sternum. A few blood vessels within the pedicle arborized over the surface of the tumor beneath the pleura. The pedicle

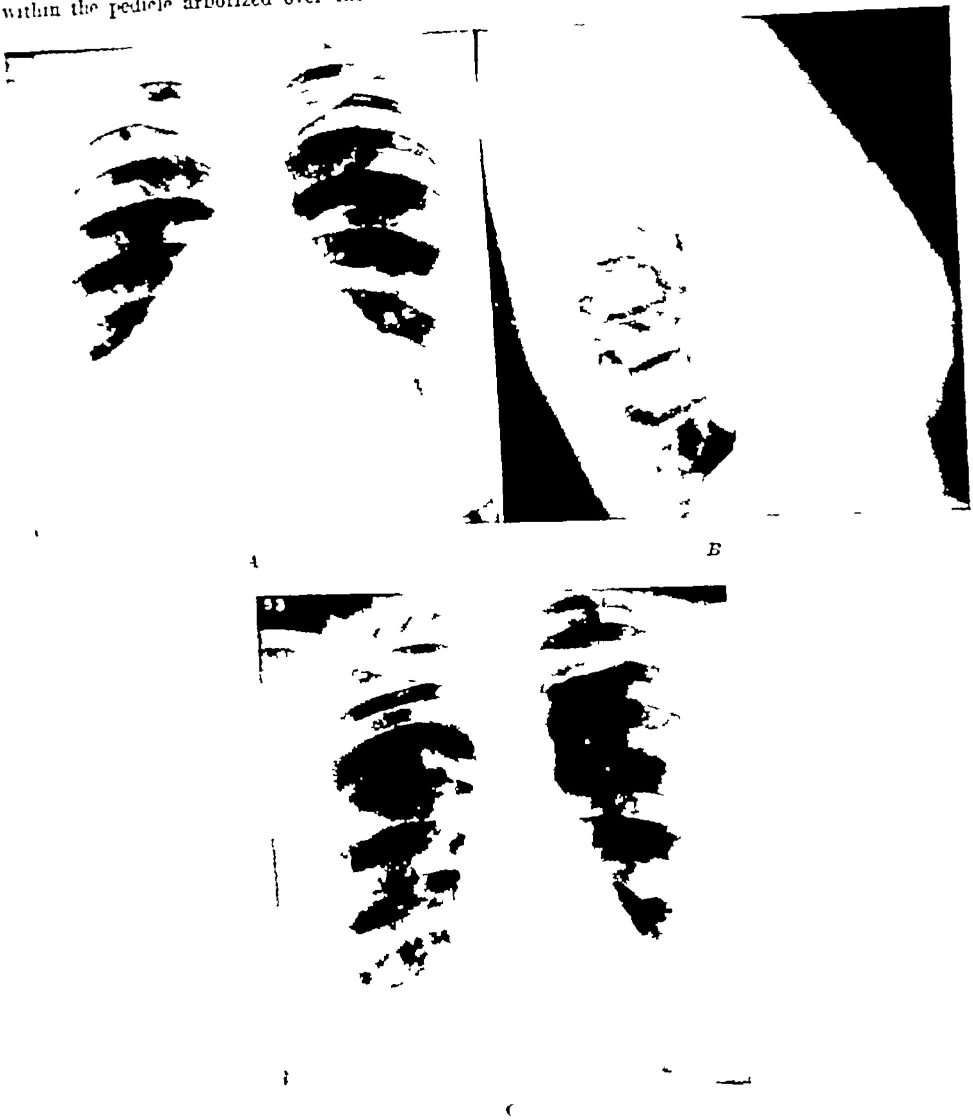


Fig. 1.—A 19 year old woman with symptoms of dyspnea and chest pain. Diagnosis of an [illegible] at the age of 14 years. A, Anteroposterior view (March 14, 1951) shows a large [illegible] with the cardiac silhouette. Note double density of periphery of mass. B, Left lateral view [illegible] the mass to be in the anterior mediastinum. C, Roentgenogram [illegible] (April 10, 1953) [illegible] months after excision of large thymic tumor of anterior mediastinum.

[illegible] clamped [illegible] the mass delivered from the pleural cavity. The [illegible] uneventful recovery and was discharged on the fourteenth hospital day. [illegible] the clinic for the past two months and is well (Fig. 1 C).

[illegible] an oval, lobulated mass measuring 20 by 12 by 10 cm. and [illegible] gm. [illegible] It was covered by a thin layer of pleura beneath which a few

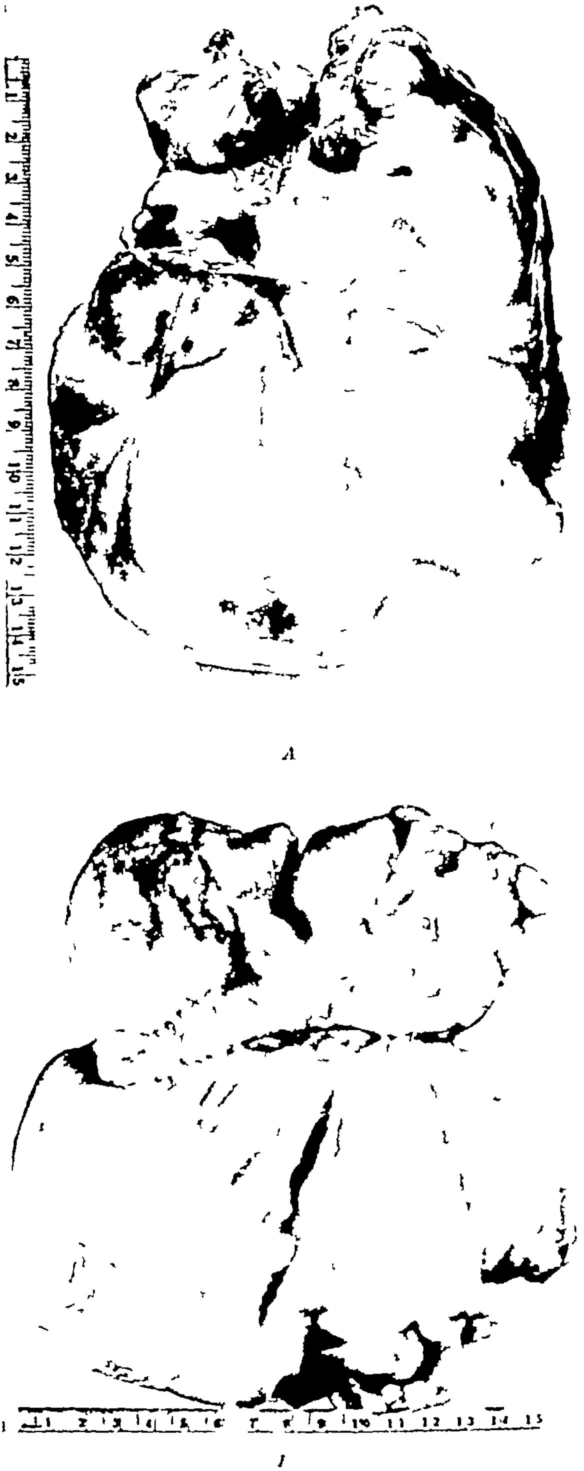
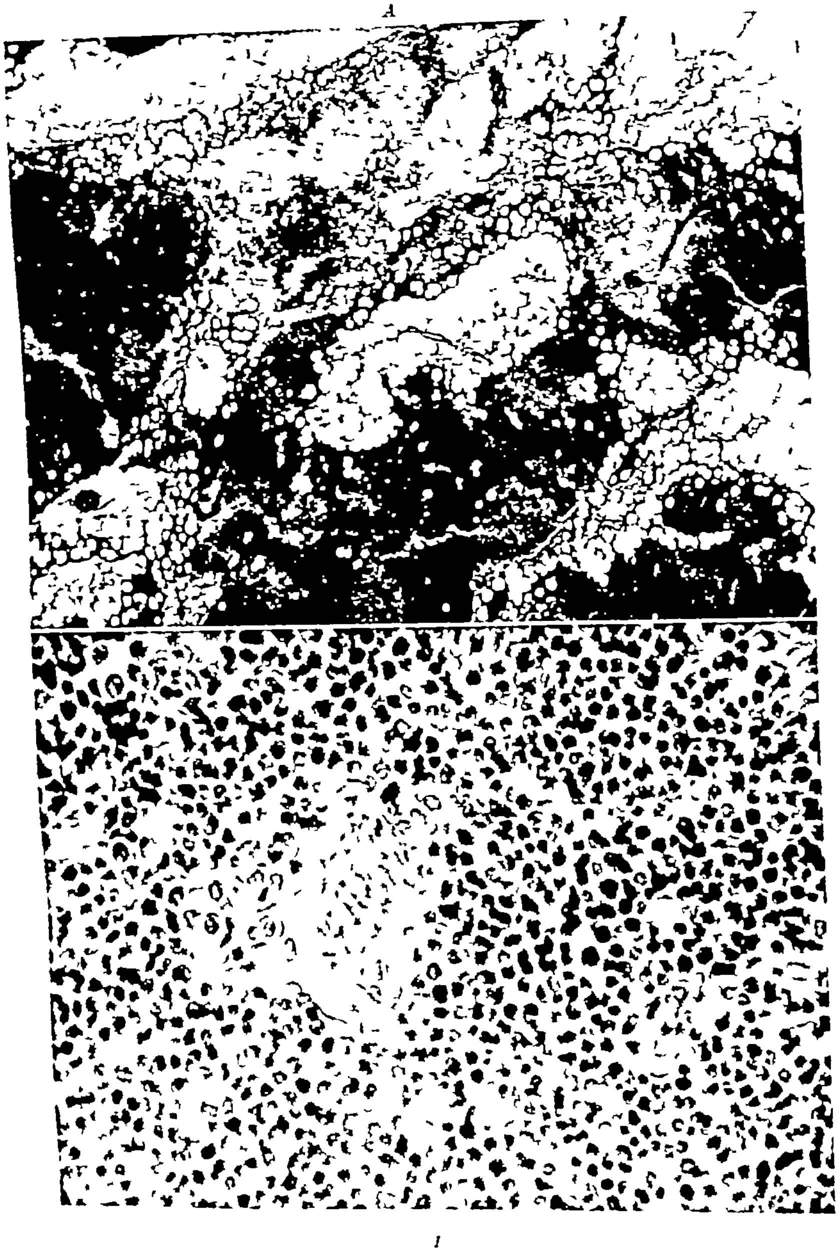


Fig. [illegible].—Surgical specimen of lobulated fatty tumor weighing 750 grams covered by mediastinal pleura. Upper pole was attached to the thymic region. Cross section showed the tumor to consist of fatty tissue with numerous dense gray areas.



F[illegible] —Mi[illegible] findings. A, th[illegible] of an admixture of thymic and fatty tissue distributed in an irregular manner throughout the tumor. The thymic portion contains both cortical [illegible] B, Hassall's corpuscles can be seen in the high power view. [illegible] (× 32) blood vessels were visible On section the tumor was found to consist of fatty tissue with numerous denser grayish areas Microscopic examination revealed a mixture of thymic and fatty tissue (Fig 3) Both elements were distributed in an irregular manner throughout the tumor mass The fatty tissue appeared normal throughout The thymic element was arranged in the lobular pattern strongly suggesting normal thymic tissue with cortical and medullary zones The cortical portions of these lobules consisted almost entirely of mature adult lymphocytes Distinct Hassall corpuscles were found sparsely scattered in the medullary portions of these lobules The corpuscles consisted of irregularly ovoid cores of amorphous basophilic material surrounded by one or two concentric rings of flattened squamoid cells with finely granular deeply eosinophilic cytoplasm and large ovoid nuclei There was no evidence of malignancy

DISCUSSION

Benign mediastinal tumors consisting of an admixture of thymic and adipose tissue are rare Only three such cases have been described previously Andrus and Foot[1] published the first such case in 1937 The patient was a 13 year old boy who was found to have a large mediastinal tumor which was producing dyspnea and cough At operation an enormous tumor weighing 2,235 grams was successfully removed The tumor was found to contain thymic tissue and fat The second case was published by Bigelow and Ehler in 1952 [2] The patient was a 10-year old girl who had cough and bloody sputum A similar thymic tumor was removed successfully The patient was followed for four years without evidence of recurrence A third case, described by Gross[3] in his recent book, was that of a thymoma removed from a 14-year-old boy, who was found to have a mediastinal mass following routine chest film examination It was thought to be a lipoma before operation At operation a tumor was found in the anterior mediastinum extending down from the left lobe of the thymus It was composed of lymphoid elements and large amounts of fatty tissue The child was well six months after operation Barety and Coury[4] quote a possible fourth case of lipothymoma treated by Houdard Unfortunately Houdard's report was not available for study

The cases cited have certain features in common They were all found in children between the ages of 10 and 15 years We are assuming that the mass in our patient was present when a so called enlarged heart was found in the chest x ray examination at the age of 14 years Such tumors may simulate cardiac enlargement as shown in a case report by Gottlieb, Baer, and Jordan In their patient, a 30 year old white man, a mediastinal lipoma, attached to the pericardium, was diagnosed originally as cardiac enlargement With the exception of the patient reported by Gross the others had symptoms referable to pressure of the tumor none had symptoms of myasthenia gravis nor was there evidence of malignancy Bigelow and Ehler coined the term, "lipothymoma which is descriptive of the disease and apparently acceptable for this type of tumor The term lipothymoma was also used by Houdard Whether or not these tumors are true thymomas or hyperplasia of both the thymic and fatty tissue is difficult to say

These rare tumors occurring apparently in children only present a number of interesting problems as to their pathogenesis and possible relationship to mediastinal lipomas The thymus originates as paired structures from the third and fourth gill arches in the same general region as those of the parathyroid gland. The structures descend laterally in the neck and, after meeting in the midline, enter the anterior part of the superior mediastinum behind the sternum. Thymic rests may occur along the course of migration into the mediastinum. The subsequent development of the thymus is one of enlargement during childhood reaching a maximum in the late teens followed by a slow involution with replacement by adipose tissue in which remnants of thymic tissue may be present. Thus it is conceivable that tumors of the thymus during this period of growth and involution may consist of both thymic and fatty components. With involution of the thymic element the lipomatous portion may continue to grow. This idea is supported by the fact that lipothymomas have not been described in the older age groups. It is also possible that a lipoma can originate from thymic fat after involution had occurred. In either case some anatomic relationship of lipomas with the thymic area should have been noted. With this view in mind an analysis was made of the recorded cases of mediastinal lipomas.

Of the fifty-eight lipomas recently analyzed by Keeley and his co-workers[21] forty-two were entirely in the anterior mediastinum, six in the cervicomediastinal region. Ten were dumbbell shaped, composed of an intra- and extrathoracic component connected by an isthmus of tissue through an opening in an intercostal space or more rarely in the sternum. Some doubt has been raised whether this last group should be included with the intrathoracic lipomas. The fact nevertheless remains that in all of these cases some anatomic relationship to the anterior mediastinum was present. Lipomas in the posterior and middle mediastinum are rare.

An analysis was made of the gross and microscopic findings of the reported cases with reference to points of attachment and possible thymic tissue remnants. In some of the cases the description of the operation or necropsy findings was too brief to permit analysis. A relationship with the thymic region was recorded in twelve of the larger tumors as may be gathered from such statements as "a pedicle extending to the suprasternal notch," "a pedicle from the arch of the aorta," "projections in the thymic area" or "projections in the superior mediastinum." An unpublished case of a mediastinal lipoma with a pedicle attachment to the thymic area which was removed surgically was described to us by Dr. J. M. Chamberlain.

Thymic remnants were mentioned in three cases of mediastinal lipomas. Such tissue was present in the pedicle in a case reported by Beatson. Similar tissue was found in the center of the lipoma in the cases reported by Bariety and Coury and Schirmer and Hodge. It is conceivable that thymic remnants might have been demonstrated in other cases if sufficient blocks of tissue were taken, particularly from the center of the tumor.

The mode of migration of the thymus helps to explain the limitation of intrathoracic lipomas to the cervicomediastinal and mediastinal region. In this respect Lemon's case is particularly interesting. The patient had a small lipoma in the supraclavicular area in addition to a large one in the anterior mediastinum which was attached to the trachea, aorta and bronchi. An example of a cervicomediastinal lipoma which was removed through a cervical incision is one reported by Graham and Wiese[18]. Whether such lipomas result from thymic rests is an interesting point of conjecture.

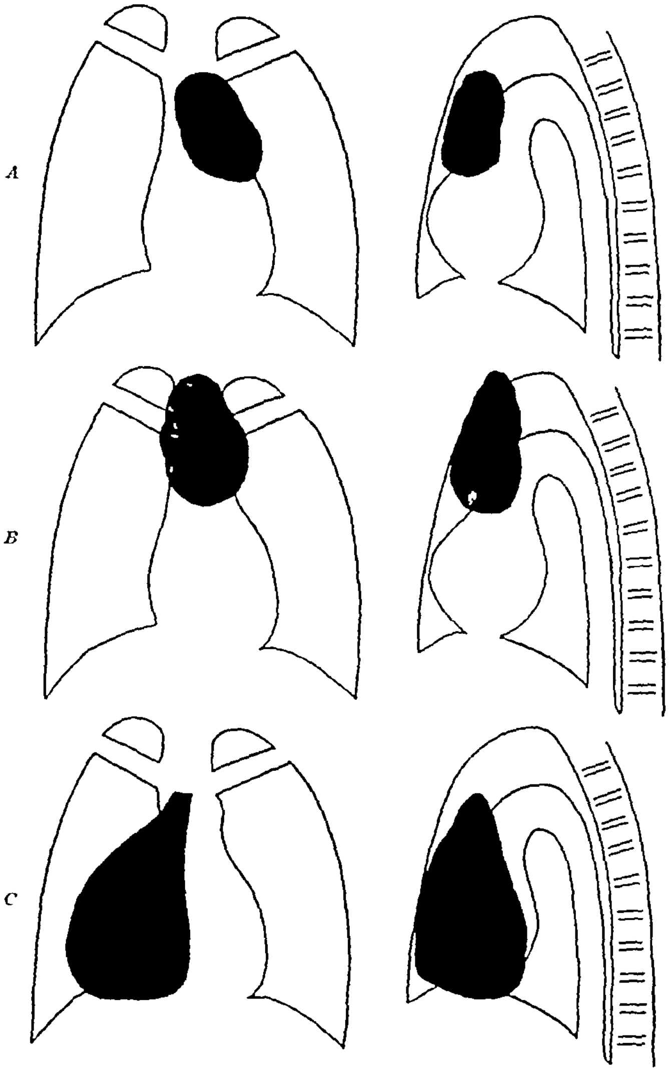


Fig. 4.—Diagrammatic presentation of the anatomic locations of intrathoracic lipomas. A, Anterior mediastinal. B, Cervicomediastinal. C, Anterior mediastinal showing downward projection of the large tumors. The resulting shape of the mass is probably influenced by its point of fixation in the thymic region and its semisolid consistency at body temperature as it comes to rest on the diaphragm.

It is thus possible to reconstruct the evolution of the larger lipomas as follows. A lipoma or lipothymoma may arise from the thymus and may remain localized to the thymic area or along its course of migration into the chest (Fig. 4, A) if its period of growth is short or if it is detected early. Such tumors may, therefore, project upward into the neck, forming a tumor of the cervicomediastinal type (4 *B*). In view of the semisolid consistency of fat at body temperature the further growth of the tumor influenced by gravity is downward. The tumor descending into the anterior mediastinum in front of the heart soon rests on the diaphragm. It there begins to spread laterally and may project into both pleural cavities or remain localized to one side. Because it maintains a fixed relation to its point of origin, it assumes a flasklike contour, a feature characteristic of such tumors before they become very large (Fig. 4, *C*). This "Erlenmeyer flask" appearance of lipomas due to their attachment at the superior pole, is clearly shown in the specimen removed by Smart and Thompson.[16]

If the tumor is discovered early in life both thymus and fatty elements may be found. On the other hand, if involution has taken place, fatty tissue predominates. Lipomas and lipothymomas of comparable size have therefore a similar radiographic appearance. Considering the age group in which the lipothymomas are found, it is conceivable that with involution of the thymic element the fatty element may persist as a lipoma. Because of the slow growth of the tumors symptoms are absent until later in life when the mass has become sufficiently large to interfere with the functions of the heart and lungs.

The relationship of the thymus to mediastinal lipomas bears resemblance to other tumors found in the same region which are also considered to originate from the same anlage as the thymus, namely, dermoids and teratomas. Hedblom divided these tumors into those of the anterior mediastinum and of the retrosternal and suprasternal areas.[22] Hourglass and presternal varieties have also been described. Rusby[25] describes dermoids as midline tumors which often have a pedicle stretching from the tumor to the center of the chest. He also mentions that the most reasonable explanation of the origin of these tumors is from abnormalities of the third and fourth gill arches, an area where development assumes a great degree of complexity due to the relationship of the various germinal layers. Schlumberger,[27] in a study of sixteen teratomas of the anterior mediastinum, held that such tumors probably arise from tissue dislocation in the anlage of the thymus. It is more than a coincidence that two tumors which are considered related to the thymus should have a comparable topographic location.

SUMMARY

A tumor of the thymus consisting of an admixture of thymic and adipose tissue is discussed. Such tumors, found in children only, have been designated as lipothymomas. Certain similarities between lipomas and lipothymomas are noted which raise the possibility of a developmental relationship between mediastinal lipomas and the thymus. A review of the embryogenesis of the thymus and the reported cases of lipomas and lipothymomas favor such a relationship.

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AN EVALUATION OF EXTRAPLEURAL PNEUMONOLYSIS WITH FILLING WITH PLASTIC BALLS

Analytic Studies on Sixty-Three Patients From Whom Plastic Balls Were Removed

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Okayama Pref., Japan

INTRODUCTION

Since Tuffier first performed extraparietal stripping in 1891 the operation has been used with modifications by thoracic surgeons all over the world. To maintain the collapse effected by extrapleural separation of the parietal pleura from the chest wall a multitude of substances have been used including air, fat, muscle, paraffin, oil, gauze, Cellophane, rubber, fiberglass wool and many other substances. For a time paraffin was widely used but because of complications especially lung perforation this method also gradually fell into disuse.

In 1948 Wilson[1] reported extrapleural pneumonolysis with Lucite plombage. Subsequently Trent and his associates[2] in 1948 reported experiences with fifty-one cases in which this method was used. Independently from Wilson in Japan in 1947 Nagaishi, Tsuji and Minoguchi[3, 4] found that Lucite in the form of spheres was inert in the extrapleural space and maintained a satisfactory collapse of the lung; they reported good results in 126 cases in 1948. However, in spite of the early good results Wilson in America, emphasized the experimental nature of the operation and warned against excessive optimism. Trent discarded this operation in January 1947 when late complications began to occur; he reported his experiences with this operation in 1948.

In Japan the simplicity of the operation and the immediate good results appealed to both the patients and the surgeons and many patients refused to have any but the "ball" operation; the indications for this operation were broadened to include those which would usually suggest thoracoplasty as the operation of choice. The operation of the plombage type was widely used throughout Japan.

Since 1949 many reports have been found in the literature in Japan. At [illegible] use of this operation. When adequate follow-up studies were made [illegible] reported results with 1064 patients who were operated

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[illegible] Annual Meeting of the Chugoku-Shikoku Section of the Japanese [illegible] Japan, Oct. [illegible] 1951 and [illegible] Twenty-fifth Annual [illegible] Japanese Association for Surgery, Okayama [illegible]

[illegible]

*[illegible] Okayama Pref., Japan.

**[illegible] Okayama [illegible]

TABLE I

CASE NO.*	INDICATION FOR PLOMBAGE	INTERVAL BETWEEN FILLING AND REMOVAL	REASON FOR REMOVAL	MEMBRANE BETWEEN BALLS	FLUID ACCUMULATION IN BALLS		LUNG PERFORATION	BLOOD LOSS DURING OPERATION (CC/KG)	RESULTS
					PRESENCE§	CHARACTER			
1	Bad (Lobité superieure)	5 mo	Empyema	Liquefied	–		+ 1		Sinus formation, at present sinus cured by reoperation
2	Good	6 mo	Empyema	Liquefied	–		–		Sinus formation at present sinus cured by reoperation
3	Bad (giant cavity)	10 mo	Positive sputum†	Hard	–		–	12.0	Good
4	Roentgenogram before plombage not available	10 mo	Empyema	Liquefied	–		–		Good
5	Bad (giant cavity)	5 mo	Positive sputum†	Hard	–		–	6.5	Temporary sinus formation, due to gauze which remained in wound at operation
6	Good	1 yr	Positive sputum†	Hard	–		–	10.7	Good
7	Bad	11 mo	Positive sputum†	Slightly fragile	–		–	10.4	Good
8	Good	9 mo	Fluid in balls	Slightly hard	+ 1	Serous, turbid	–	4.7	Good
9	Bad	1 yr, 5 mo	Positive sputum†	Slightly fragile	+ 1	Pus	–	5.8	Good
10	Good	6 mo	Positive sputum‡	Hard	+ 1	Pus	–	Severe	Operative death
(11)	Bad	7 mo	Fluid in balls	Fragile	+ 1 br	Pus	–	8.1	Sinus formation cavity entered
12	Bad (Lobite superieure)	2 yr, 5 mo	Lung perforation	Liquefied	– br		+ 6	Severe	Operative death
(13)	Bad (Lobite superieure)	1 yr, 11 mo	Empyema	Liquefied	– br		+ 1	14.3	Good
14	Good	1 yr, 9 mo	Positive sputum‡	Fragile	+ 4	Serous brownish	Necrotic 2 punctured	11.0	Good
15	Bad	2 yr	Positive sputum‡	Fragile	–		–	8.2	Good

Footnotes on p 506

TABLE I—CONT'D

CASE NO.*	INDICATION FOR PLOMBAGE	INTERVAL BETWEEN FILLING AND REMOVAL	REASON FOR REMOVAL	MEMBRANE BETWEEN BALLS	FLUID ACCUMULATION IN BALLS		LUNG PERFORATION	BLOOD LOSS DURING OPERATION (CM./KG.)	RESULTS
					PRESENCE§	CHARACTER			
16	Bad	2 yr 10 mo	Empyema	Liquefied	+ *1 br*	Pus	–	13.8	Good
(17)	Good	2 yr 6 mo	Wish	Fragile	–		–	12.8	Good
18	Good	2 yr 7 mo	Fluid in balls	Fragile	+ *1*	Serous	–	5.8	Good
19	Bad	2 yr	Fluid in balls	Slightly fragile	+ *2*	Bloody	–	14.6	Good
20	Bad	1 yr 2 mo	Wish	Fragile	–		–	7.1	Sinus formation
21	Good	3 yr, 4 mo	Fluid in balls	Fragile	+ *2*	Pus	–	14.9	Good
(22)	Bad	2 yr, 2 mo	Lung perforation	Slightly hard	+ *1 br*	Pus	[illegible]	10.5	Wound separation
23	Good	2 yr, 6 mo	Wish	Slightly hard	–		–	12.3	Good
24	Good	2 yr, 6 mo	Wish	Hard	– *br*		–	11.6	Wound separation
25	Bad	2 yr, 4 mo	Empyema	Liquefied	–		–	7.4	Good
26	Good	2 yr 6 mo	Positive sputum‡	Fragile	–		–	13.2	Good
27	Good	2 yr 2 mo	Positive sputum‡	Fragile	+ *1*	Pus	+ 1 autopsy	Severe	Operative death
28	Good	2 yr 1 mo	Fluid in balls	Liquefied	+ *1*	Pus	–	8.4	Good
29	Bad	2 yr, 6 mo	Positive sputum‡	Fragile	–		–	15.1	Good
30	Good	2 yr	Wish		+ *2*	Serous black	–	10.7	Good
31		3 yr 3 mo	Fluid in balls		+ *3 br*	Pus	–		
32	Good	2 yr 8 mo	Positive sputum‡		–		–	6.1	Good
33	Good	1 yr., [illegible] mo	Fluid in balls	Fragile partly hard	+ *2*	Serous	–	10.9	Good
34	Good	3 yr	Hemoptysis	Fragile	–		–	8.3	Good
35	Bad	2 yr, 3 mo	Positive sputum‡	Fragile, partly liquefied	+ *1*	Pus	–	11.8	Good
36	Good	1 yr 9 mo	Fluid in balls	Fragile	+ *1*	Pus	–	5.5	Good
37		1 yr 10 mo	Wish	Fragile	–		–	4.2	Good
38	Good	1 yr 11 mo	Fluid in balls	Fragile	+ *1*	Serous brownish	–	9.2	Good
39		2 yr [illegible] mo	Empyema	Liquefied	–		–	11.7	Good
40	Bad	2 yr 1 mo	Fluid in balls	Fragile	+ *2 br*	Serous brownish	–	13.3	Good
41	Good	2 yr [illegible] mo	Fluid in balls	Fragile	+ *1*	Serous brownish	–	14.8	Good
42	Bad	2 yr [illegible] mo	Positive sputum	Fragile	–		–	7.4	Good
43	Good	2 yr [illegible] mo	Positive sputum	Fragile	–		–	15.2	Sinus formation

[illegible]

TABLE I—CONT'D

CASE NO.*	INDICATION FOR PLOMBAGE	INTERVAL BETWEEN FILLING AND REMOVAL	REASON FOR REMOVAL	MEMBRANE BETWEEN BALLS	FLUID ACCUMULATION IN BALLS		LUNG PERFORATION	BLOOD LOSS DURING OPERATION (CM./KG.)	RESULTS
					PRESENCE§	CHARACTER			
44	Good	3 yr., 1 mo.	Fluid in balls	Fragile	+ *2*	Serous brownish	-	13.0	Good
45	Good	2 yr., 6 mo.	Fluid in balls	Fragile, partly liquefied	+ *3 br*	Pus	-	8.2	Wound suppuration
(46)	**	2 yr., 6 mo.	Increased sputum	Slightly hard	*1*	Serous	-	9.0	Good
47	**	2 yr., 8 mo.	Positive sputum‡	Hard	-				Good
48	Good	2 yr., 3 mo.	Fluid in balls	Liquefied	+ *8*	Pus	-	14.1	Good
49	Good	2 yr., 3 mo.	Wish	Slightly hard	-		-	14.1	Good
50	Good	1 yr., 11 mo.	Fluid in balls				-	9.2	Good
51	Good	2 yr., 1 mo.	Fluid in balls	Hard	+ *1*	Serous, fibrin mass	-	18.2	Good
52	Good	3 yr., 1 mo.	Fluid in balls	Partly hard	+ *1*	Pus	-	5.5	Good
53	Good	1 yr., 9 mo.	Fluid in balls	Fragile	+ *1*	Pus	-	6.7	Good
54	Good	2 yr., 9 mo.	Fluid in balls	Hard, partly liquefied	+ *2*	Serous, fibrin mass	-	11.2	Good
55	Good	2 yr., 3 mo.	Fluid in balls	Fragile	- At operation fluid was not found		-	8.7	Good
56	Good	2 yr., 11 mo.	Empyema	Liquefied	+ *2*	Serous	-	14.7	Good
57	Good	[illegible] yr., 6 mo.	Fluid in balls	Fragile	+ *1*	Pus	-	8.4	Good
58	Bad	3 yr., 2 mo.	Fluid in balls	Fragile	+ *[illegible]*	Serous brownish	-	8.6	Good
59	Good	2 yr., 7 mo.	Empyema	Liquefied	+ *8 br*	Pus	Necrotic, 2 punctured	8.9	
60	Good	2 yr., 3 mo.	Fluid in balls	Fragile	-		-	12.6	
61‖	Bad	2 yr., 5 mo.	Positive sputum†	Fragile	-		+ 1		Sinus formation
62	Bad	1 yr., 2 mo.	Positive sputum†	Hard	-		-	10.6	Good
63	Bad	2 yr., 9 mo.	Positive sputum‡	Hard	-		-	9.1	Good

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*The case numbers which appear in parentheses indicate that the patient was operated on at a hospital other than the National Okayama Sanatorium.

**Roentgenogram before plombage not available.

†Positive sputum in direct smear.

‡Positive sputum in concentrated smear.

§The italicized numbers indicate the number of balls in which fluid was accumulated. *br* indicates breakage of a ball.

‖Plombage following thoracoplasty in Cases 61, 62 and 63.

upon by March, 1949, at forty national sanatoriums and on whom follow-up study was carried out from five months to two years after the operation (80 per cent after five to eleven months), showed 50 per cent had improved, 32 per cent were unchanged, 7 per cent were unimproved, and 6 per cent were dead. Complications reported from the operation included twenty-four postoperative cavity perforations (2.2 per cent), four cavity perforations during operation, eight bronchopleural fistulas, thirteen sinus formations, seven tuberculous extrapleural empyemas, and eight nontuberculous empyemas. One year later he[7] reported that lung perforation increased from 2.2 per cent to 7.5 per cent and empyema from 0.6 per cent to 3.5 per cent in the same series. The incidence of these complications widely varied in each sanatorium. It is generally accepted that the less involvement of the lung there is before operation the fewer the complications that will occur. Nagaishi[7] reported eleven perforations (2.8 per cent) in 393 cases. Sawazaki[8] reported 5.4 per cent in 148 cases at National Hiroshima Sanatorium in 1950. The highest reported incidence of lung perforation was 17.8 per cent in 90 cases in Kamo National Sanatorium.[6]

Today surgeons in sanatoriums are busily occupied in removing these balls. In National Okayama Sanatorium from May, 1948, until March, 1950, ninety-seven patients were operated upon by this method, a total of 106 operations was performed. Up until this time three operative deaths, one death due to hemoptysis with lung perforation, six lung perforations, and six empyemas have occurred, and in fifty-seven cases extrapleural plastic balls were removed for varied reasons. It is evident that the longer the cases are followed up the more the complications become evident. This report is based on an analysis of sixty-three cases, in which extrapleural plastic balls were removed from the patients. We feel that it is important to report our experiences with this reoperation at this time, for little literature is available on operations of this type. The practice of removing the extrapleural plastic balls is spreading and some dangers accompany an operation of this kind.

ANALYSIS ON REMOVAL OF EXTRAPLEURAL PLASTIC BALLS

In total sixty-three operations were performed on sixty-two patients. Of these sixty were primary plombage and three were plombage following thoracoplasty in which the cavity had not been closed (Table I). The reasons for the removal of the plastic balls are shown in Table II.

In Table I in the column headed "Indication for Plombage" the word *good* refers to a patient who was in good general condition and had a localized lesion

TABLE II. REASON FOR REMOVAL OF PLOMBAGE

REASON	NO. OF PATIENTS
1. Extrapleural empyema	6
2. Lung perforation	2
3. Fluid accumulation in balls	27
4. Positive sputum	18
Patient's wish	8
6. Hemoptysis	1
7. Increase of sputum	1

in upper lung field with small cavity situated at a distance from the chest wall or without evident cavity and whose sputum contained scanty tubercle bacilli or no bacilli. *Bad* refers to a patient, who had a large cavity, especially one situated close to the chest wall, or so-called "lobite supérieure" (extensive lesion) and also those patients whose sputum was highly laden with acid-fast bacilli. Complications occurred more frequently in patients who had bad indications. But it is noteworthy that in the course of time postoperative complications, especially the side effects of the plastic ball itself such as fluid accumulation in the balls, markedly increased irrespective of preoperative indications.

OPERATIVE FINDINGS

1. *Lung Perforation.*—At operation perforation of lung was found in four patients; one was not clinically detected prior to operation. A small, brownish black necrotic change on the parietal pleura which was considered as the beginning stage of perforation, was found in two patients.

2. *Extrapleural Empyema.*—Empyema was found in nine cases, in 3 of which it was not diagnosed preoperatively.

3. *Fluid Accumulation in Balls.*—Fluid accumulation in the plastic ball was found in thirty-two cases. Seventeen of the thirty-two were suppurative including apparently tuberculous granulation mass, others were serous or slightly turbid and their color varied; some contained a fibrin mass or a granulomatous mass. Broken plastic balls were found in nine patients, and in most fluid was existent. In eleven cases the tubercle bacillus was detected by culture from these. It is noticeable that fluid accumulates more or less in the balls in the course of time, for this suggests that inflammation, mostly tuberculous infection, occurs in the extrapleural space sooner or later.

4. *Capsule Between the Balls.*—The membrane between the balls was very firm in cases which did not elapse so long after plombage. Therefore in these early cases, the removal of plastic balls was moderately difficult technically except in empyema cases. In fact, in one case the balls were so firmly embedded that removal was impossible without endangering the patient's life. In one case the attempt was abandoned after seven balls had been removed and the cavity had been entered; this case developed tuberculous wound infection. But in later cases in which more than two years had elapsed after plombage the membrane between the spheres was usually fragile and tuberculous granulation tissue existed in most cases. Therefore removal of balls was relatively easy in these cases. Of course in empyema cases the membrane was completely dissolved and the balls were afloat in pus.

OPERATIVE TECHNIQUE

This operation is generally more difficult and blood loss during operation is greater than in an ordinary primary thoracoplasty, for the periosteum is hard and the rib is fragile due to the pressure caused by the balls. In many cases when the apex of the lung had been pushed down by the previous operation it was unnecessary to resect the first rib and transverse process, but it is our routine procedure to strip the periosteum of the first rib to reduce extrapleural space and thus to prevent the re-expansion of the lung. In one stage it is possible to resect five ribs (from the second to the sixth) for the lung has been moderately collapsed by plombage and the effects on the cardiorespiratory system by rib resection are less than in ordinary primary thoracoplasty. The operative wound was always primarily closed in spite of the existence of lung perforation or empyema.

Of the three patients with lung perforation, one had wound separation and two developed a sinus. But in empyema cases all were cured primarily. Of course, the operation is to be divided and sufficient rib resection is to be performed in the cases in which the lesion of the lung has not been controlled by plombage or in poor-risk cases, that is, rib resection is to be limited to the extent of obliterating the extrapleural space in cases in which the lung lesion has been controlled by plombage.

OPERATIVE RESULTS

There were three operative deaths. These will be briefly described. Postoperative complications are summarized in Table III. It demonstrates that operative complications occur more frequently than in the usual primary thoracoplasty.

TABLE III

POSTOPERATIVE COMPLICATIONS	NO. OF PATIENTS
1. Operative death	3
2. Temporary sinus formation	1
3. Tuberculous sinus formation	3
4. Sinus formation with bronchial fistula	2
5. Wound separation with bronchial fistula	1

CASE REPORTS

CASE 1 (Case 10, Table I).—T. I., a 23-year-old man, was admitted to National Okayama Sanatorium on Sept. 2, 1949. He complained of a small amount of cough and sputum. Concentrated sputum was "loaded" with tubercle bacilli on smear. Direct radiogram of chest revealed slightly dense infiltration in the left upper lung field, and a productive nodular shadow was visible in right upper field. On Nov. 10, 1949, left extrapleural pneumonolysis with plastic balls was performed; on May 15, 1950, right plombage was performed. After plombage the patient's general condition was good and the complaints almost disappeared but sputum was occasionally positive by concentration method. Therefore, removal of left extrapleural plombage was attempted on Nov. 21, 1950. All balls were very firmly embedded and removal was very difficult. On removal of the last ball embedded in anterior apex massive bleeding abruptly occurred. Because the control of the bleeding was impossible the wound was primarily closed in three layers after tight gauze packing. Postoperative course was dramatic. Marked swelling of the left chest and neck appeared and the patient complained of tightness and dyspnea. But neither [illegible] nor bleeding from wound occurred. On the fourteenth postoperative day removal of gauze pack was made. At that time no bleeding occurred but on the eighteenth postoperative day massive hemorrhage from wound occurred and subsequently 5 similar [illegible] followed. On the twenty-sixth postoperative day he died from fatal hemorrhage. Autopsy was not allowed. I think the azygos vein was injured upon removal of the last ball.

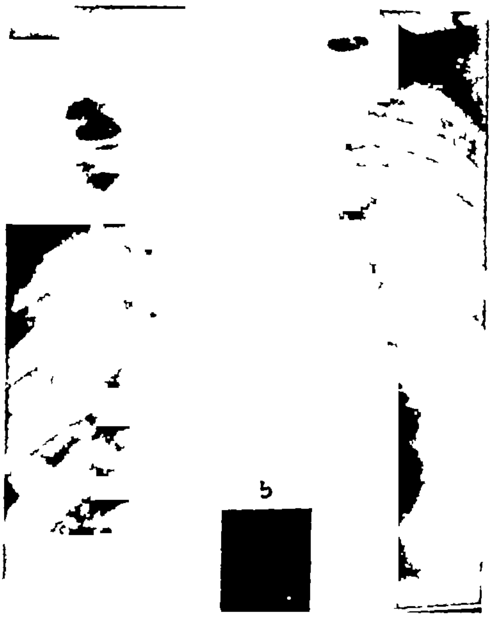


Fig. 1.—(Case 2.) Posteroanterior roentgenogram of the chest showing right extrapleural plombage (Dec. 18, 1950).

Fig. 2.—A, Left anterior bronchogram showing lung perforation (Feb. 9, 1951). B, Right lateral bronchogram.

CASE 2 (Case 12, Table I)—K Y, a man, 28 years of age, was admitted on July 22, 1948, complaining of cough and thick yellow sputum, which was positive for tubercle bacilli A roentgenogram of the chest, made on admission, revealed a dense shadow including a cavity in right upper lung field, a so called "lobité supérieure" Right extrapleural pneumonolysis with plastic balls was performed on Nov 26, 1948 Stripping was difficult due to hard thick pleura and only four balls were inserted Clinical symptoms remained unchanged after plombage Because of the positive sputum the removal of the plastic balls and a thoracoplasty was indicated Direct radiogram showed no changes in the extrapleural space and balls, but preoperative bronchogram revealed lung perforation, which we did not expect (Figs 1 and 2) On March 23, 1951, the removal of the plastic balls was attempted As soon as the balls were removed three perforations were found Because the patient was unconscious during operation, due to excessive use of narcosis (1 0 cc of 4 per cent Pantopon scopolamine and bleeding severely, he aspirated blood through a lung perforation and died from suffocation on the operating table At autopsy, there were found six perforations of large and small sizes ranging from 1 to 5 mm, which directly communicated to three segmental bronchi of the upper lobe

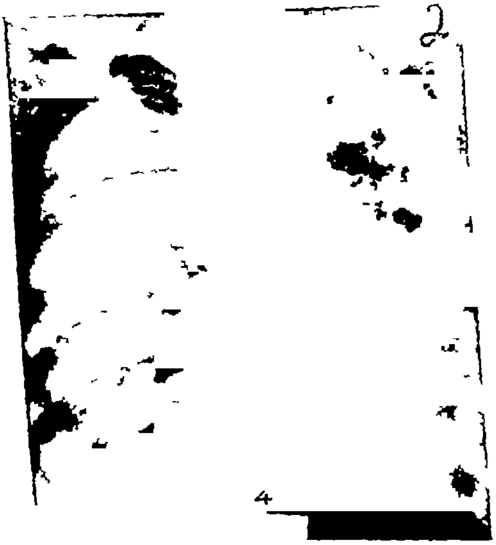
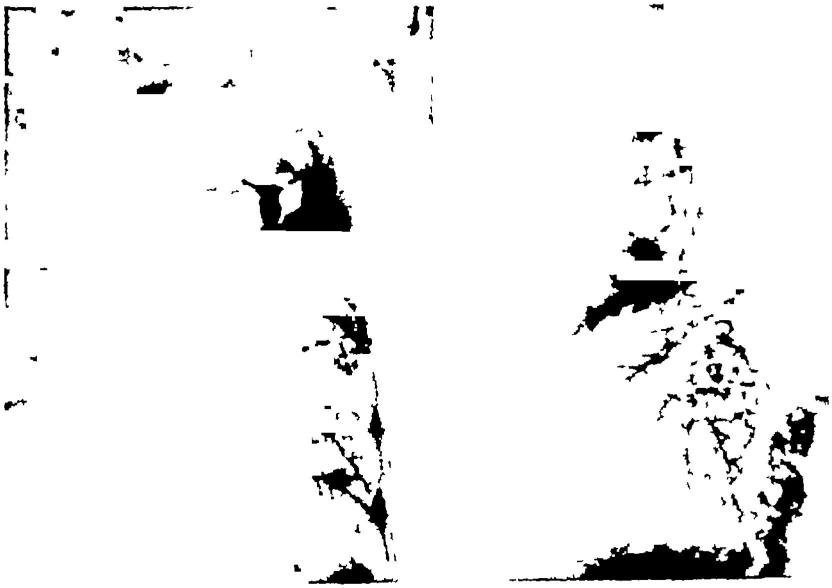


Fig 2 —(Case 2) Posteroanterior roentgenogram of chest showing left extrapleural plombage (May 10 1951)

CASE 3 (Case 22, Table I)—K M, a 37 year old man, was admitted on July 9, 1950 He had undergone left extrapleural pneumonolysis with plastic balls in another hospital in July 1949 Complaints included cough and sputum, positive for tubercle bacilli on direct smear A roentgenogram of the chest, made on admission, revealed a lung moderately collapsed by Lucite ball plombage and a thin diffuse shadow, suspected of being bronchogenic spread below the plombage on left side and scattered nodular shadow in right lower lung field There was no fluid in the balls and extrapleural space, but the medium between the balls was blurred and thin, suggesting liquefaction He was occasionally feverish but the patient's general condition was good Bronchogram revealed lung perforation (Figs 3 and 4) On Sept 21, 1951, removal of the plastic balls was attempted [illegible] and six lung perforations were found Wound was closed primarily On the [illegible] postoperative day wound separation occurred and tuberculous mucopurulent [illegible] was discharged and bronchopleural fistula developed At present a change of [illegible] daily Prognosis is considered poor

CASE 4 (Case 27, Table I).—F. W., a 25-year-old woman, was admitted on July 28, 1949. Roentgenogram made on admission revealed scattered productive nodular shadow in the left upper lung field. She had a small amount of cough; sputum was positive for tubercle bacilli on concentrated smear. On Sept. 20, 1949, left extrapleural pneumonolysis with plastic ball was performed. After plombage the patient had no clinical symptoms but the sputum remained occasionally positive. Direct radiograms after plombage showed no change. On Nov. 6, 1951, removal of balls was attempted. Because the membrane between the ball was fragile and partly liquefied, removal was easy. Upon removal of the last ball situated in the medial part, without any rough handling massive bleeding abruptly occurred. Since it was considered impossible to control the bleeding, gauze packing and primary tight closure of wound was made. Postoperative course was uneventful except for slight dyspnea until the fourth day. On the fifth postoperative day massive hemoptysis occurred and subsequently daily hemoptysis continued and the patient died of fatal hemoptysis on the twentieth postoperative day. It was thought that a large vessel might have been eroded by plastic balls. Autopsy revealed small perforation of left subclavian artery and a 2 mm. perforation of the lung. Erosion by the pressure of plastic balls on the arterial wall was not detected. The perforation may be attributed to a technical failure in the operation, but if there had not been a lung perforation, she might have survived.



A *B*

Fig. 4.—*A*, Posteroanterior bronchogram showing lung perforation (Aug. 8, 1951). *B*, Lateral bronchogram.

COMMENT

Extrapleural pneumonolysis with plombage is a desirable operation. It is not surprising therefore that repeated attempts have been made to find an ideal material for a pack substance. It has been emphasized that plastic is an inert material in the body. However, many of the same late complications appear as usually attend the use of other packing materials. Of these complications lung perforation is most serious and occurs more frequently with plastic balls than through other packs. Soon after the use of plastic balls for plombage dense hyaline tissue forms around the balls which is so hard that Trent[2] reported that in one case removal of the spheres post mortem required a mallet and chisel. It is noticeable that this dense hyaline capsule becomes fragile in the course of time and changes to tuberculous granulation tissue in many instances. Sputum conversion after plombage is also less than in thoracoplasty. Our results justify discarding the use of plastic balls in the extrapleural space. Patients who have undergone this operation, even if at present they are at work in good condition, must be periodically observed.

SUMMARY

1. Sixty-three cases of removal of extrapleural plastic balls, in which extrapleural pneumonolysis with filling of plastic balls five months to three years and three months before had been carried out, were analyzed.

2. At operation four lung perforations, two necrotic changes on the pleura, which are considered the beginning stage of perforation, and nine extrapleural empyemas were found.

3. The membrane between the balls had become fragile in the course of time and removal of plastic balls was easy in most cases when more than two years had elapsed after plombage.

4. Rib resection after removal of the balls must be limited to the extent of obliterating the extrapleural space. The resection of five ribs, from the second to the sixth, in one stage is not dangerous. The first rib and transverse process need not be resected.

5. As operative complications there were three operative deaths, seven sinus formations, and one wound separation. Operative complications occur more frequently than in usual primary thoracoplasty.

6. Preoperative bronchography is useful for detection of bronchopleural fistula.

7. Plastic balls are not suitable for pack material in the extrapleural space.

My hearty acknowledgments are due to Professor S. Tsuda for his guidance.

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PATHOGENESIS OF BRONCHIECTASIS

EXPERIMENTAL STUDY AND ANATOMIC FINDINGS

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THE problem brought about by the study of the pathogenesis of broncho pneumonectasis is one of the most complicated in pulmonary pathology. Known for many years, this condition has been studied by numerous authors who, on the whole, contributed elements considered of importance for the knowledge of, if not for the pathogenesis of, bronchial dilatations.

Laennec,[1] in 1826, thought that the increase of retained secretions was an important factor in the pathogenesis of such bronchial alterations. Corrigan,[2] in 1838, stated that the sclerosis and condensation of the lung (pulmonary cirrhosis) are alterations which precede the bronchial dilatations. Hasse,[3] in 1841, also agreed with the theory that bronchiectasis appears when the lung decreases in size. Virchow,[4] in 1846, pointed out for the first time that the dilated bronchi are nearly always covered by cylindric ciliated epithelium. Von Biermer,[5] in 1860, compiled in a special paper the available data up to that time on bronchiectasis; he pointed out the mechanical factors (pressure of the retained secretion, increase of the pressure of the air, and pulmonary retraction) and the nutritional factors (pathologic alterations of the alveolar and bronchial walls) which were capable of producing the condition. Stewart,[6] in 1867, pointed out, as Virchow had done previously, the integrity of the epithelium and the destruction of the muscular elastic layers.

Thornton and Pratt, in 1908, diminished the importance of coughing as a factor of the dilatation. In 1923, Nissen[8] produced, experimentally, bronchial dilatations by means of bronchial ligatures in dogs, cats, and guinea pigs; he noted the rapid dilatation which followed the retained secretion of mucus, although infection did not necessarily begin. In 1931, Erb[9] carried out an anatomo-pathologic study in a large number of cases and stressed the importance of bronchial infection in the origin of bronchiectasis. Robinson,[10] in 1933, after an extensive anatomic study reached the conclusion that the essential alteration was a weakening of the muscular elastic layer which was produced by inflammatory parietal processes. Jones and Cournand,[11] in 1933, carried out a study of poststenotic bronchiectasis. Warner,[12] in 1935, after a statistical study believed the most important factor to be the bronchial infection. Lemoine,[13] in 1936, assigned great importance to thrombosis and arteriosclerosis of the bronchial arteries. In 1937, Weinberg[14] carried out tests on rabbits and reached the conclusion that atelectasis and retained secretions are factors of great importance. Jennings[15] (1937) believed atelectasis to be the most important factor and pointed out, for the first time, the existence of reversible bronchiec

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tasis. In 1937, in an exhaustive study, Andrus[16] analyzed the causes capable of producing bronchial dilatation and denied, categorically, the dilating mechanism of cough. Adams and Escudero,[17] in 1938 carried out an experimental test which had great repercussion. In their tests a partial obstruction was considered the responsible factor in bronchiectasis.

Lander and Davidson[18] in 1938 stated that the mechanical factors are the important ones and that the infection which destroys the wall must be considered as a secondary event, for bronchograms of patients suffering from bronchiectasis taken during inspiration and expiration show the dilatation and contraction. Hamman[19] in 1939 believed that the bronchiectasis, which apparently does not follow an obstruction, does not differ from the obstructive type. He stated: "The origin of bronchiectasis can only be satisfactorily explained when bronchial stenosis is demonstrated. In those cases in which the bronchi are permeable one has to believe that the stenosis has existed though transitorily."

Fleischner[20] in 1940 with arguments based exclusively on radiologic findings gave importance to atelectasis as a dilating factor. Ogilvie,[21] in 1941, in a synthesis including all of the supposed causes of bronchiectasis, mentioned until that time, divided the causes into two groups: defects of the bronchial wall and various forces which are associated with the bronchial wall. In 1942 Tannenberg and Pinner[22] carried out a number of tests on rabbits and came to the conclusion that atelectasis is not followed by bronchiectasis, unless an infectious process begins. Lisa and Rosenblatt,[23] in 1943, presented anatomic arguments which favored the infection hypothesis. Riggins,[24] in 1943, believed that the cause of the dilatations was to be found in the destructive infection of the wall and that the collapse or retraction of the lobe was a secondary fact. Also in 1943 Vaccarezza and Leston[25] established that the increase of the endothoracic negative pressure is secondary to the bronchoalveolar hypopressure; they did not consider the latter a determining element or even one that favored bronchiectasis in the obstructive apneumatosis.

Blades and Dugan[26] in 1944 reported cases of reversible bronchiectasis (which they named pseudobronchiectasis). In 1945 Renault[27] stressed the importance of the alterations of the bronchial wall and came to the conclusion that the principal factor was a profound alteration of the parietal muscular elastic layer. Lander[28] in 1946 stated that any theory which wished to explain the formation of bronchiectasis must also explain the formation of emphysema; he added that all bronchiectasis is at the beginning reversible, becoming later permanent due to the rigidity of the parenchyma. Mallory[29] in 1947 in an excellent study pointed out that any theory explaining the pathogenesis of bronchiectasis must also agree with the explanation of the four constant clinical and anatomic characteristics: (1) why bronchiectasis is very seldom diffuse; (2) why it is not progressive and does not attack other lobes; (3) why it seldom appears as an isolated anatomic abnormality; and (4) why it is an illness of youth and not of old age. Churchill[30] in 1949 pointed out the importance the mucous secretions had in bronchial dilatation in cases of stenosis. During the same year 1949 Croxatto and his associates[31] stated that the dilatation was only the direct effect of a pathologic process which harms the bronchial and parenchymatous tissues sufficiently to interfere with the normal function. Fleischner[32] (1949) thought that the atelectasis produced by the obstruction of the small bronchioles was the cause of the bronchial dilatations.

This series of chronologic findings, although not complete, shows how little is known about bronchial dilatations. What is even more apparent is that the destruction of the wall and atelectasis have been considered, in general, the cause of bronchiectasis and not the effect.

It is very difficult to study the pathogenic problem, although we have passed the period when the study of bronchiectasis was carried out as a post-mortem investigation (and therefore corresponded to individuals with severe bronchial infections). At the present time the anatomic study of human bronchiectasis is not useful in obtaining data referring to the primary alterations for the study is performed on lungs which have been removed by surgery and these correspond to patients who present an evident symptomatology and, therefore, established lesions. Added to this is the fact that experimentally only obstructive bronchiectasis may be obtained, it seems that the complexity of the problem would make it practically unsolvable.

Because of the great morphologic similarity between bronchiectasis of the obstructive type and that apparently of a nonobstructive nature, we believe that both respond to the same mechanism. With this in mind, we have carried out experiments in dogs and have also studied twenty cases of human bronchiectasis in surgically removed lobes. With the dogs we hoped to determine: (1) which was the factor responsible for the bronchial dilatation in cases of stenosis, (2) the course of this dilatation, and (3) if the dilatation was permanent or reversible. With the specimens from the human beings we hoped to discover if any elements existed which could confirm or deny the action of a dilating factor coming from the interior of the bronchus.

MATERIAL AND METHOD

Work was carried out on seventy mongrel dogs, weighing approximately 10 kilograms. Intraperitoneal chloral morphine was used as a general anesthetic, the animals were operated upon while intubated and connected to hyperpressure systems. After incising the skin and muscular layers at the level of the fifth left intercostal space, the ribs were separated and the left bronchus was ligated by means of two thick cotton ligatures, only a few millimeters apart. *It is of interest to note that in the first dogs operated upon the bronchus was ligated with only one ligature and the obstruction was only partial, a small orifice, sometimes the size of a pinhead, remained and atelectasis could not be obtained.* The wall was closed in layers, the dogs were given penicillin postoperatively. The dogs were sacrificed at different intervals ranging from a few hours postoperatively to six months postoperatively.

Several dogs were reoperated upon after a time. After removing one of the lobes, the stenosed segment of the main stem branch, where the ligature had been placed, was also excised and the lumen was re-established either by means of a plastic tube or an evaginating continuous suture. Before doing this, as much mucus as possible was aspirated, after the suturing the remaining lobe was re-expanded by hyperpressure through the tracheal tube.

On several dogs before sacrifice we tried to measure the bronchial pressure below the stenosis by means of a Hamilton manometer but difficulties attributed to the great viscosity of the mucus made it impossible to obtain exact readings

The twenty specimens demonstrating human bronchiectasis were taken from twenty patients whose only illness was the bronchial alteration Their ages ranged from 18 to 40 years These twenty lobes were taken from a number of patients without any previous selection in order that they should possess the characteristics of representative samples The study was also carried out in some cases of secondary bronchiectasis due to bronchial carcinomas or adenomas

RESULTS

Bronchial Obstruction in Dogs —

In some of the dogs it was not possible to produce atelectasis because a total bronchial stenosis was not obtained Other dogs showed suppurating bronchopneumonic processes but in the great majority, 52 animals, bronchial dilatations were obtained which presented specific characteristics These are the only ones to which we will refer

Six days after the ligature had been performed, the bronchi appeared macroscopically dilated and full of an adherent mucus Due to the great pressure exerted by the mucus on the bronchial wall a constant factor was the spontaneous and rapid flow of the mucus when the bronchi communicated with the exterior either by means of the sections of the lung or by means of the opening of the air duct (Fig 1) In every case the surrounding parenchyma showed atelectasis The longer the interval allowed before sacrificing the dogs the greater was the bronchial dilatation obtained, after the second month the caliber of the dilatation became uniform that is after the period of two months the dilatation did not increase and the size remained unchanged in every case

Macroscopically no bronchial dilatation was observed before the sixth day following the stenosing ligature although by means of microscopic observation the presence of bronchial collapse was observed in the first postoperative hours the dilatations commenced in the following days The histologic study carried out fifteen hours after the bronchial ligature had been performed showed the disappearance of the bronchial lumen due to collapse of the walls (Fig 2 A) Once this first condition of bronchial collapse which lasted twenty-four hours had passed the bronchi started to dilate due to the continuous secretion of mucus and the interruption of the normal flow to the exterior This dilatation was obtained during the first postoperative days due to the unfolding of the bronchus It is necessary to remember that the bronchus of the dog has characteristics similar to that of a human being but that the mucous membrane in dogs presents numerous folds which makes the dilatation possible only with the stretching of the epithelium and the flattening of the submucosa (Fig 2 B and C

Some structural modifications became apparent in the epithelium the number of the goblet cells increased and surpassed the number of the ciliated cells The epithelium became higher than normal The bronchial glands showed [illegible] tions and there were no changes in the muscular tissue (Fig 2 D) The bronchial lumen was occupied by mucus with some macrophages and very few polynuclear leukocytes. In the noncartilaginous bronchi the epithelium was also of a greater height than normal and showed a great quantity of goblet cells. It is of interest to point out that although the bronchial diameter increased up to twice its original caliber, no regressive alterations of the cells were found and no detachment of the cilia; this indicated a certain capacity of dilatation, for if this were not the case these elements would suffer alterations due to the pressure to which they were subjected.

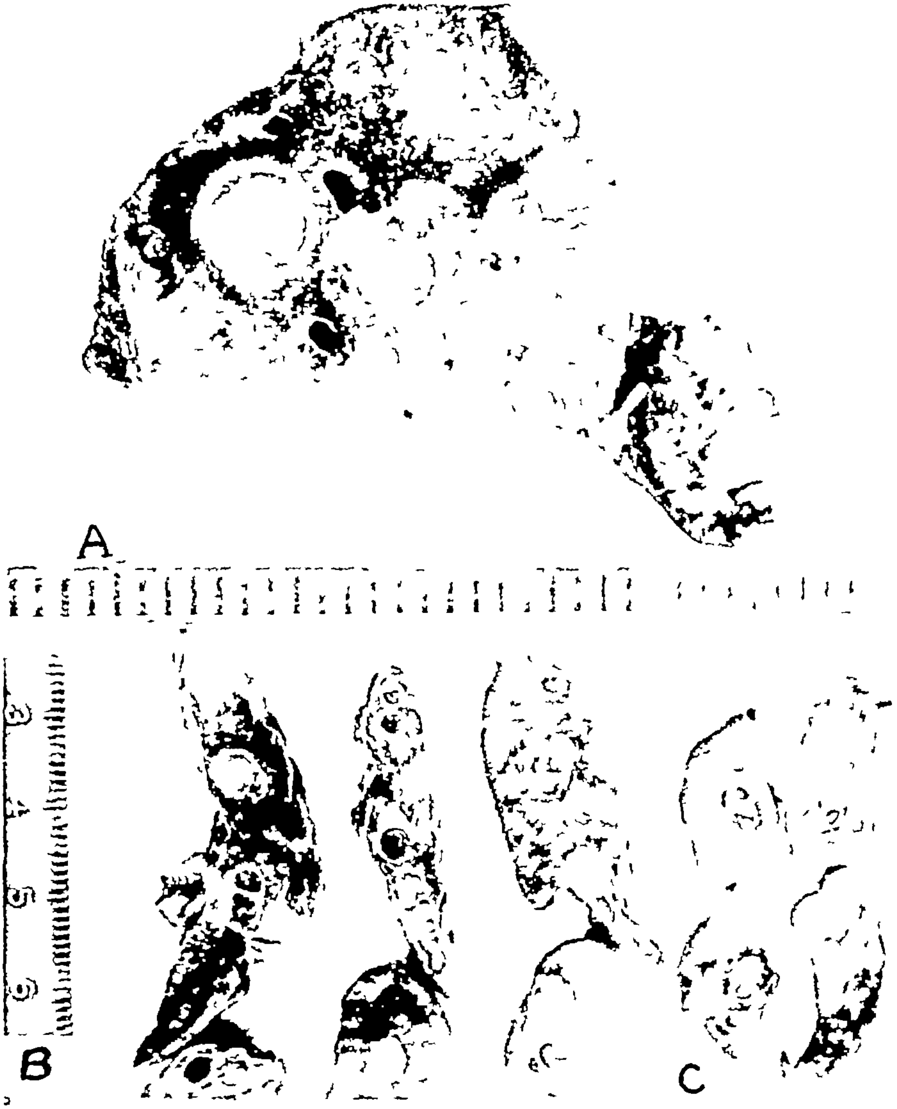


Fig. 1.—A, Transverse section of a pulmonary lobe of dog three months after a stenosing ligature was produced. Note the protrusion made by the mucus. B, Sections of a lobe of a dog one month after the stenosing ligature. C, Section of a dog's pulmonary lobe twenty days after the stenosing ligature had been produced. The mucus has been extracted to show the bronchial dilatation.

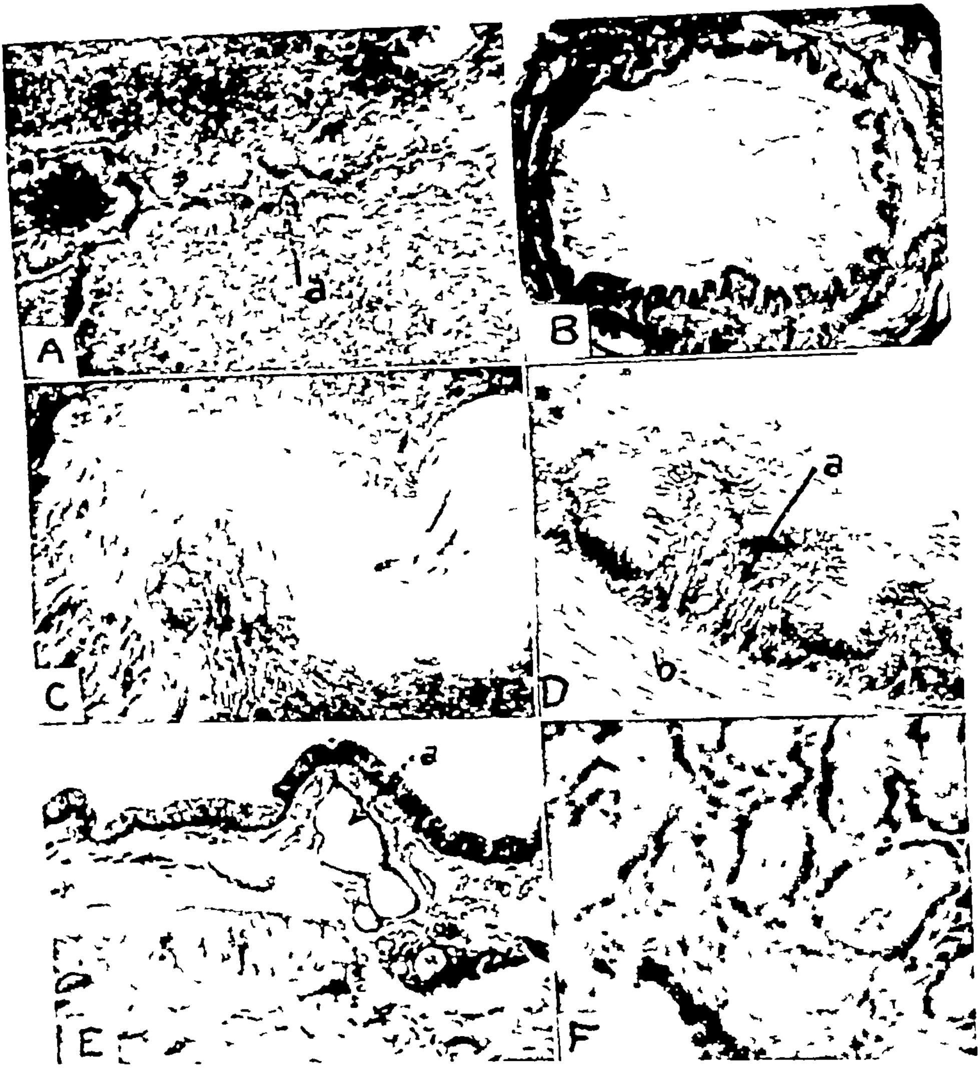


Fig. 2.—A, Longitudinal section of a dog's bronchus (a) fifteen hours after the stenosing suture had been [illegible] The surrounding parenchyma is intensely [illegible] (hematoxylin and eosin; [illegible]). B, Transverse section of a dog's bronchus ten days after the obstruction was produced. Unfolding is nearly complete; structures are conserved [illegible] C, Longitudinal section of a dog's bronchus twenty-five days after the suture [illegible] with the total unfolding of the mucous membrane [illegible] mucus [illegible] (hematoxylin and eosin; [illegible]). D, Specimen of a bronchial wall of a dog [illegible] the bronchial obstruction was produced; a shows total compression of the [illegible] (hematoxylin and eosin; [illegible]). E, Specimen of a [illegible] months after the obstruction was produced. Total unfolding of [illegible] bronchial glands [illegible] appearance of the excretory [illegible] the lumen [illegible] glandular dilatation [illegible] F, Dilated [illegible] with [illegible] which correspond to [illegible] after the bronchial obstruction was produced (com[illegible]

After a time and once the endobronchial pressure had reached a point in which it inhibited the secretion of the bronchial glands, the excreting ducts of the glands became dilated, and the period of maximum dilatation with glandular exhaustion was attained (Figs. 2, *E* and *F* and 3, *B*). Mucus was found not only in the bronchi and bronchioles, but also in the alveolar ducts; it was an interesting finding to see that a connective tissue organization of the mucus was started in the bronchioles (Fig. 3, *A* and *C*). After about two months had elapsed since the stenosis was produced, the submucosa became infiltrated with round cells, lymphocytes in their greater part, and within a very short time a true cuff surrounded the air ducts.

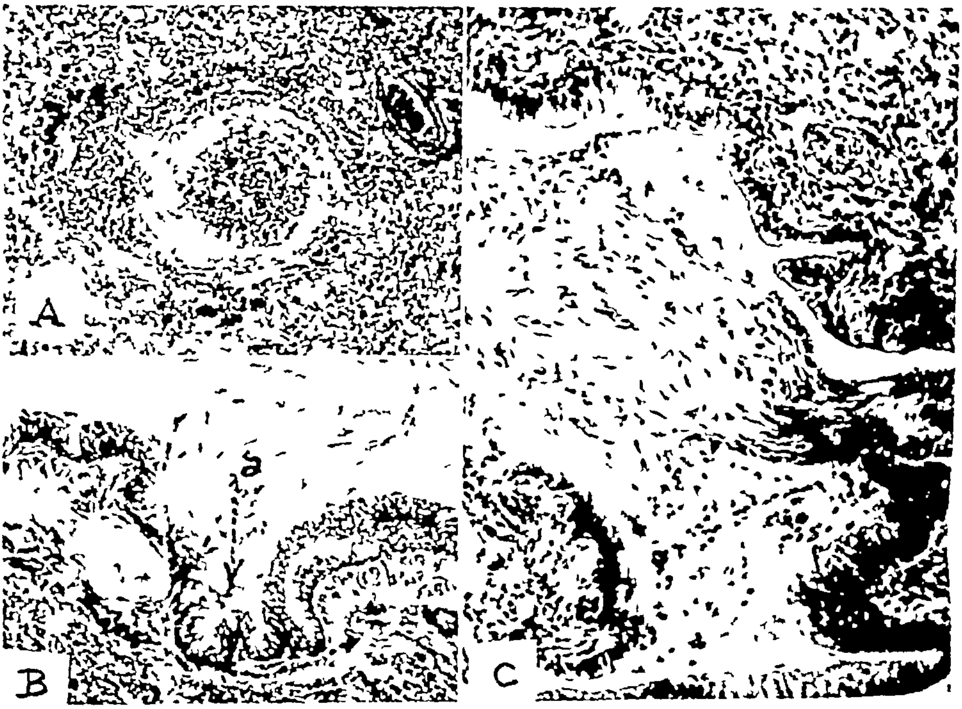


Fig. 3.—*A* and *C*, Bronchiolar organization of the mucus. In *A*, within a small bronchiole, a nodule infiltrated with lymphocytes may be seen (dog three months after the obstruction was produced) (hematoxylin and eosin ×150). *C*, Small bronchus of a dog two and one half months after the obstruction. Mucous organization. Note the fibroblastoid cells which seem to come from the bronchial epithelium (hematoxylin and eosin ×250). *B*, Bronchus of a dog one month after the obstruction. Total unfolding with apparent disappearance of the submucosa. *C* Corresponds to an amply dilated excretory duct.

In summarizing the observations made from the dogs, it may be stated that once the bronchial stenosis was established, the air was reabsorbed from the respiratory parenchyma and also from the bronchi. As the mucus, which continued to be secreted by the bronchial glands and the goblet cells, did not find an external outlet, it dilated the bronchus. This was made possible first by compression of the mucous membrane and flattening of the chorion. Later there was dilatation of the excreting ducts until a time was reached (approximately two months) when the pressure of the mucus within the bronchus was higher than the resistance offered by the cells of the acinus which ceased to secrete mucus. Thus the dilatation of the bronchi and bronchioles became stabilized then the connective tissue organization with bronchiolar obstruction commenced in the small bronchioles and in some small bronchi We will refer later to the importance of this latter finding

In those instances where the lobe was removed changes similar to those just listed were observed Survivals after recanalization were obtained and were of two six nine and ten days Difficulties of a technical nature made a correct recanalization impossible The remaining lobe showed atelectasis in two dogs in another an inflammatory process was added and the dilatations remained as a definite bronchiectasis (Fig 4 A) In the dog that survived ten days a partial recanalization was obtained although the bronchial dilatations persisted as such in the absence of any infection (Fig 4 B)

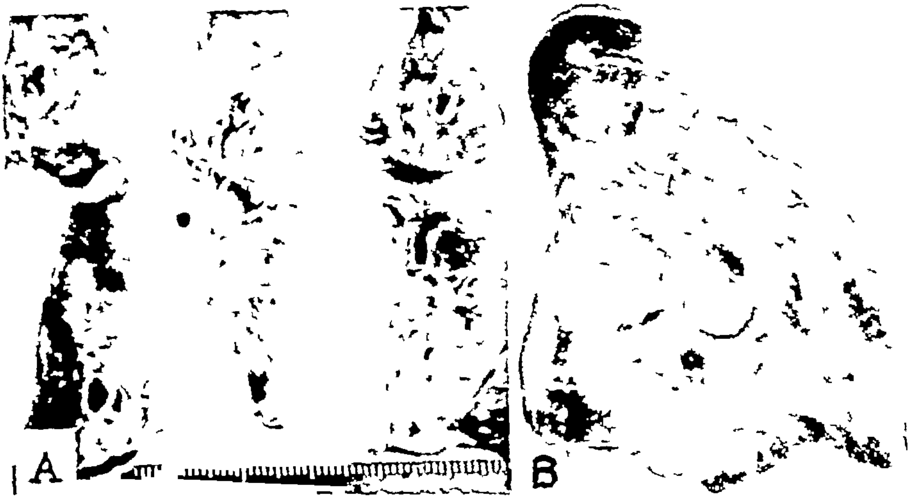


Fig 4 — A Sections of a dog's lung several days after the recanalization of the bronchus which had been obstructed five months Definite bronchiectasis may be observed as an inflammatory process set in The lobe removed for control purposes showed at the time of the recanalization mucous bronchodilatation B Dog's lung ten days after the bronchial recanalization was attempted The obstruction existed during six months The bronchial dilatation did not show any accompanying inflammatory process The lobe extracted for control purposes showed mucous bronchodilatation ×3

Even though this last group of animals was small and the results obtained due to technical difficulties not too clear the results do show that infection superimposed to the dilatation produced by retained secretions led to the production of bronchiectasis and that in some cases even though the dilating material was extracted the bronchus remained dilated

Human Bronchiectasis —

Of the twenty patients studied only four showed serious inflammatory processes In the remaining sixteen slight or no inflammatory processes were observed In the majority parenchymatous alterations existed which consisted of sclerosis atelectasis emphysema and bronchial proliferation In very few the parenchyma presented normal characteristics

The microscopic examination of the bronchiectasis showed

Epithelium Practically all the bronchi presented epithelium of the cylindrical ciliated or stratified type with a great quantity of goblet cells and was in general of a greater thickness than the normal lining epithelium. Even in the small and dilated bronchi the epithelium showed hypertrophic characteristics. This is a histologic fact that repeats itself with extraordinary constancy in all bronchiectasis without infection.

Bronchial Submucosa.—In the large bronchi, the submucosa was thinned and showed some zones where the epithelium laid directly on the cartilage. In the small bronchi a lymphocyte infiltration of a varied degree was observed in the submucosa and peribronchus.

Elastic and Muscular Tissues.—In general, in those cases without infection the characteristics were normal. We omit the description of small details of thickening, fragmentation, and reduplication of the elastic fibers which some authors have observed and which we corroborate, even though they lack importance.

Cartilage.—In all dilated bronchi, cartilaginous alterations of the regressive type were found: calcification, ossification, and sometimes even formation of bone marrow.

Peribronchus.—The condition of the peribronchus varied, in some cases sclerosis was observed and in others the characteristics were normal.

Bronchial Glands and Excretory Ducts.—In these elements histologic findings of the greatest importance were observed. The glands, according to the degree of dilatation attained by the bronchus, were normal or completely atrophied passing through degrees of true acinous dilatation with formation of small cysts. In the bronchi with a greater dilatation it was difficult to individualize the glands, while in those cases in which the dilatations were not great the glands showed characteristics similar to normal; other intermediate cases existed in which the acini were full of mucus and the cells flattened (Fig. 5, *B*). The corresponding excretory ducts showed alterations related to the glandular alterations from normal to completely dilated; there existed some zones, easily individualized, in which as a result of the great dilatation, the epithelium of the duct formed part of the bronchial epithelium. As a result of these dilatations of the excretory ducts, either partial or complete, the underlying bronchial submucosa and epithelium took on the appearance of papillae (Fig. 6, *A* and *B*).

The bronchial arteries showed, in general, a thickened wall and hyperplasia of the intima of the disused arteritis type. This fact has been observed by the majority of those studying bronchiectasis although receiving different interpretations.

To summarize, we may say that in cases of bronchiectasis without a serious infection, which constitute the great majority of cases, the histologic examination generally showed normal epithelium and musculoelastic structures, lymphocyte infiltration of the submucosa, and alterations (*of a possible anoxic nature*) of the bronchial cartilage. Sometimes there were rigidity of the peribronchus and dilatation of the glandular excretory ducts.

In the pulmonary parenchyma which surrounds the bronchiectasis obstructive pneumonitis was found which alternated with areas of emphysema. The bronchioles were dilated and many showed mucous bronchiolitation.

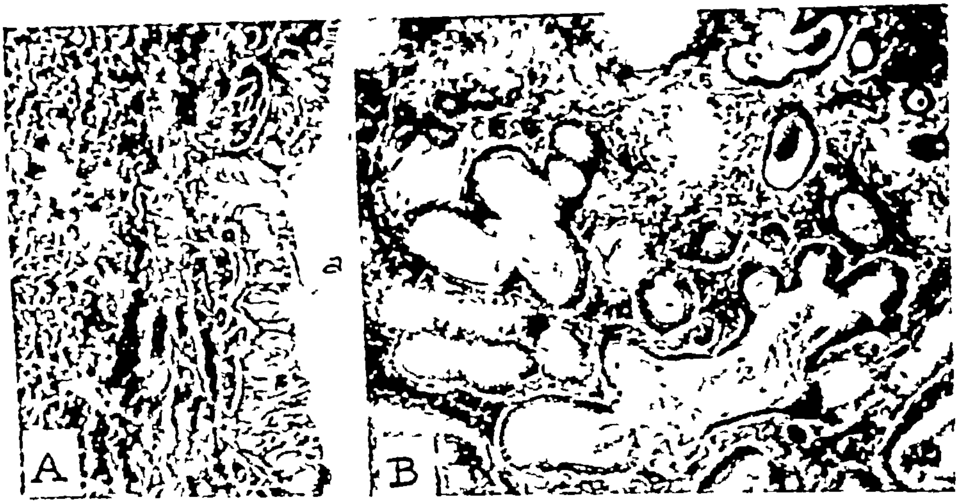
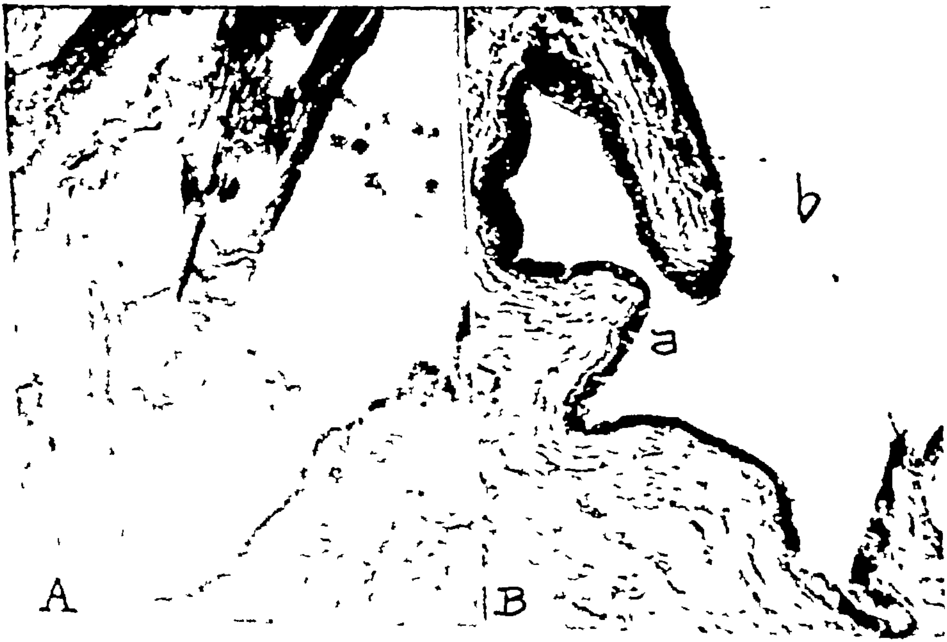


Fig. —1 Wall of a human bronchiectasis total unfolding of the mucosa (large quantity of goblet cells (*a*) apparent disappearance of the submucosa (hematoxylin and eosin [illegible]) *B* Human bronchiectasis Dilated glands which contain mucus and flattened cells (hematoxylin and eosin [illegible]) Compare with Fig 2 *B*



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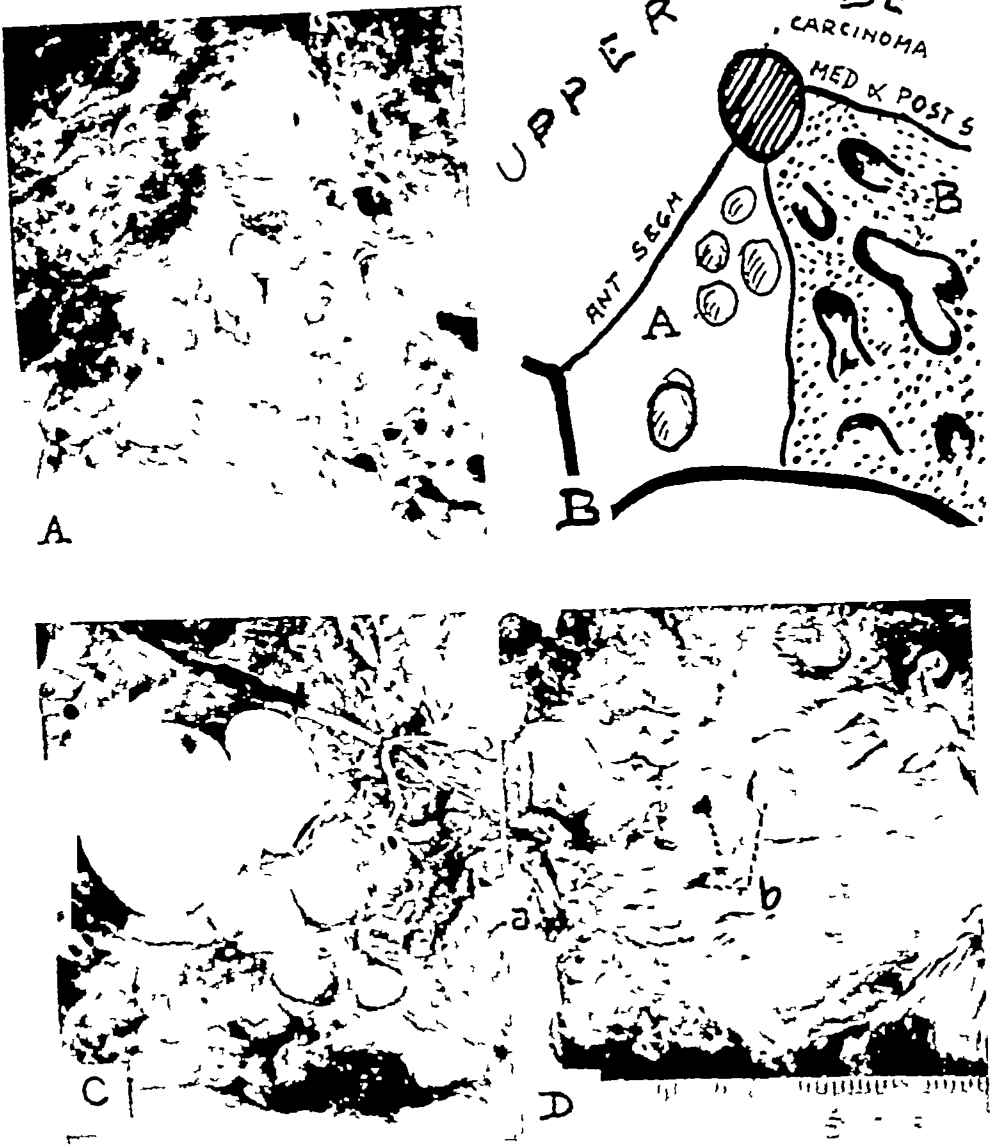
DISCUSSION

The results obtained from the experiments with dogs and from the study of the material of human bronchiectasis allow us to answer the questions we asked at the beginning of this paper.

The Responsible Factor of Bronchial Dilatation in Cases of Stenosis.—Even though the atelectasis was supposed by many authors to be the cause of the dilatation, it is only a contemporary factor of the process, but without any causal importance. In fact, once a bronchial obstruction is obtained the atelectasis is produced by diffusion of the alveolar air and reabsorption of the air which remains enclosed in the bronchi below the stenosis. As the secretion of mucus by the bronchial glands is not interfered with and since this secretion does not find an outlet to the exterior, the bronchus becomes dilated. At the beginning the arrangement of the structures of the mucous membrane makes the dilatation possible without any alteration of the underlying structures. In the short time of six days, dilatations of macroscopic appearance are obtained. For descriptive purposes we will call these dilatations "mucous bronchodilatations" and list them as the first condition of all obstructive bronchiectasis. We refer as an example of this statement to a case of carcinoma located in the bronchus of the left lower lobe in which the intrabronchial growth obstructed first the bronchi of the posterior and medial basal segments where there existed at the time when the study was performed definite bronchiectasis. In its later growth the tumor obstructed the bronchus of the anterior segment, and in this segment mucous bronchodilatations were observed surrounded by atelectatic parenchyma, similar in every way to the observations in dogs (Fig. 7, *A* and *B*). Also as an example we offer the cases of bronchial adenoma in which below the stenosis great mucous bronchodilatations are found and when an infection is added, bronchiectasis is produced (Fig. 7, *D*).

Evolution of the Dilatation Beyond the Stenosis.—In dogs the dilatation progresses until maximum dilatation is reached (after approximately two months) in which the glands are inhibited and the flow of mucus ceases. While the large bronchi dilate there is a flow of mucus from the glands, but once the bronchi cannot dilate any further the flow ceases and organization of the retained mucus begins (Fig. 3, *A* and *C*). We do not know what mechanism leads to this proliferation of mesodermic and mesenchymatic elements the final result of which is the total or partial bronchiolar obstruction, but it may be likened to what occurs in the blood vessels in cases of detention of the blood flow and also with the organization which follows the deposit of fibrin on the serous surfaces. The consequence of this bronchiolar obstruction will be the inability to re-expand when the obstruction becomes complete and generalized and emphysema as well as incomplete re-expansion when it is neither complete nor generalized.

Is the Mucous Bronchodilatation Reversible or Permanent?—Jennings[1] Blades and Dugan and Ochsner reported cases of reversible bronchiectasis. We do not doubt that such a thing may occur since nothing prevents mucous



[illegible] Carcinoma of a bronchus of the left inferior lobe. Definitive bronchi[illegible] and posterior segments (B) mucous [illegible] bronchiolar dilatations in the [illegible] (C). Mucus [illegible] obliteration in a case of bronchial obstruction caused [illegible] (D) [illegible] definitive bronchiectasis (b) by an inflam[illegible]

[illegible] a reversible process in the early stages, as at the beginning the bronchi [illegible] dilated and there are no bronchial or parenchymatous [illegible] months in the case of dogs it is difficult for these [illegible] reversible for bronchiolar fibrous obstructions and destructive [illegible] As a consequence of this the [illegible] the lobe does not [illegible] and emphysema and obstructive pneumonitis occur when the stenosis of the bronchioles is not total. Due to the glandular destruction the infection of the bronchial wall is made possible.

Technical difficulties did not allow us to obtain conclusive results with regard to the reversibility of the mucus bronchodilatations. A dog, on which a lobectomy was performed six months after and in which a partial pulmonary recanalization was obtained, maintained its bronchial dilatations (Fig. 4 *B*), another, subjected to the same experiment, survived only a few days after the lobectomy and, as a consequence of the added inflammatory process, the bronchodilatations became definite bronchiectasis (Fig. 4, *A*). In the other dogs a good re-expansion was not obtained, and although at the time of the lobectomy the greatest possible amount of mucus was extracted the bronchi persisted dilated for several days.

We believe, however, that the mucus bronchodilatations are reversible processes at the beginning, irreversible after a certain time when parenchymatous alterations and inflammatory processes of the walls are added.

Findings Which Affirm, in Human Bronchiectasis, the Existence of a Dilating Factor Proceeding From the Interior of the Bronchus.—The alterations encountered in human bronchiectasis lead us to believe that the inflammatory lesions of the bronchial walls are secondary and are of no importance or value at the beginning of the bronchial dilatations. This is based on the observation of sixteen patients of a total of twenty, who did not present inflammatory lesions; this is also in accordance with observations made by other authors.

All alterations found in the bronchi tend to show that the increase of the internal pressure is the cause of the bronchial dilatation. To use an example which would give a clear idea of our observations in bronchiectasis we can say that it would be as though the normal bronchus were strongly inflated from one of the ends, and as a consequence the folds would be ironed out. The findings cannot be explained by external stretching but only by the increase of pressure from within.

Therefore our findings would indicate the possibility that apparently nonobstructive bronchiectasis is the consequence of a previous obstruction. The reason that in some cases of definite bronchiectasis the obstructing element is not found, is not, we believe, an important argument to rule out the hypothesis for, as has been observed in dogs, the rapidity with which the mucous bronchodilatations begin is remarkable. If we bear in mind that the bronchiectasis represents processes localized to one or two lobes and which do not extend to other lobes and that in certain cases they are reversible, it is well understood that there may exist a transitory obstructive element which disappears leaving reversible or definite bronchiectasis.

We have expressly left for the end one point of discussion which we believe upholds the obstructive mechanism of the primary human bronchiectasis. We refer to bronchial proliferation. This name is given to small ducts of an irregular contour covered by cuboid epithelium placed in the center of the pulmonary parenchyma which has undergone a process of postatelectatic sclerosis. Its significance is difficult to understand. Some authors give it the value of a collateral aerial circulation.[24] This must not be mistaken for the lining of the alveolus. It is of a completely different origin. In the case of the fifty two dogs used for the study, we never found it, while we came across it in the twenty examples of human bronchiectasis studied. This finding which seems a discordant fact actually is not. For the animals presented definite atelectasis and when in some of them the bronchial obstruction was relieved the later survival was short, a useful re-expansion was not obtained. In the twenty human beings studied however there did not exist any bronchial obstruction at the time the study was made. That is, that if both groups are in a certain manner comparable, the one referring to human bronchiectasis is a much later condition. If we consider that apart from this bronchial proliferation great areas of sclerosis and disappearance of bronchioles are found as was mentioned by Rokitansky[illegible] more than a century ago and recently by Reid, we are led to the belief that the bronchiolar obstruction is the cause of the segmentary atelectasis and the bronchial proliferation is a phenomenon which follows re-expansion. We therefore, believe that bronchial proliferation constant in human bronchiectasis indicates the previous existence of atelectasis and a later recanalization. This bronchial proliferation occurs not only in bronchiectasis but is observed in all cases of partial atelectasis. It is not observed when a permanent atelectasis exists such as in the cases of the dogs studied.

The problem to be solved at this time is to find out which is or which are the cause or causes capable of obstructing the bronchi without leaving any traces.

CONCLUSIONS

1. Complete bronchial obstruction leads to bronchoalveolar apneumatosis. The secreted mucus not finding an external outlet dilates the bronchus (mucus bronchodilatation).

2. The mucus bronchodilatation constitutes the first phase of every obstructive bronchiectasis.

3. The mucus bronchodilatations may, once the bronchus becomes recanalized, disappear at the beginning or become permanent later (bronchiectasis) as a result of the bronchiolar obstruction or as a consequence of an accompanying infection.

4. It is probable that all bronchiectasis, acquired, primary or secondary, is caused by a bronchial obstruction.

W[illegible] [illegible] to Dr. O[illegible] V[illegible] Chief Thoracic Surgeon, for his valuable suggestions [illegible] dealing with bronchiectasis in human beings. We also acknowledge the [illegible] assistance of Mrs. M. L. O. d[illegible] Carvalho and Miss [illegible]

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RATIONALE AND A NEW SURGICAL TECHNIQUE IN TRAUMATIC CHYLOTHORAX

WITH REPORT OF A CASE

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WE PRESENT a re-evaluation of the treatment of traumatic chylothorax and a few ideas concerning the definitive surgical technique that may be utilized for injuries to the thoracic lymphatic system.

Portrayed is the situation with which one may be faced and how simple mechanically the solution may be.

The following tenets are proposed:

1. Assiduous clinical and roentgenographic follow-up of cervical, thoracic and abdominal injuries, whether penetrating in type or not, is necessary.

2. There should be close nutritional support to compensate for loss of chyle.

3. If daily completely evacuant thoracenteses do not alleviate cardiac or respiratory embarrassment or leakage of chyle does not subside, we believe in closed (tube) drainage with suction applied. Despite the alleged bacteriostatic property of chyle, a thoracostomy tube or tubes should not be present longer than seven to ten days lest empyema supervene.

4. If the lung does not expand fully, thoracotomy should be considered seriously. A golden period of seven to fourteen days after trauma exists for operative attack before inanition and collapse occur. Suture of a leak in a bronchus or the pulmonary parenchyma, a plastic procedure on the duct, or simple ligation may turn the tide. The normal apposition of visceral to parietal (mediastinal) pleura may be all that is necessary, and the cohesive, adhesive and tamponade effect of the fully inflated lung may be curative in itself.

INCIDENCE

Up to 1895 Bargebuhr[1] had been able to collect only forty cases, and he estimated that one occurred every six years. Felts[2] declared that many clinicians of wide experience have never encountered a case. Military surgeons reported no such case during the Civil War, according to Lillie and Fox.[3] We found no mention of chylothorax in *The History of the Medical Department of the United States Army in the World War*. Perry[4] has discussed the only case reported as occurring in the American Army during World War II. Until 1935 only eighty [illegible] cases were reported.[5] Olsen and Wilson[6] revealed that until 1944 only nine such cases were treated at the Mayo Clinic. While reviewing the [illegible] Whites [illegible] found that fifty-four cases were in the journals prior to

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[illegible]

1918 and forty-five during the period from 1918 to 1949. During the 1949 convention of the *American Association for Thoracic Surgery*, six additional cases were discussed, according to Butt.[7]

HISTORY

Macnab[29] reported that Asellius in 1627 was the first to describe the lymphatic system. Thirty-six years later, Longelot (Cellan Jones[10]) wrote of the clinical entity of chylothorax. The first authentic case of traumatic chylothorax was detailed by Qincke in 1875 (Lillie and Fox[21]). Intravenous chyle in the therapy of this discouraging catastrophe was first administered by Oeken in 1908 (Butt[7]). We believe the first case in the English literature to be that of Williamson in 1920.[49] Van Nuys[46] in 1931 reported the use of roentgen therapy. First to report bilateral chylothorax with associated chylous ascites of traumatic origin was Brown[5] in 1937. During the same year, Bauersfeld[1] published a report concerning the second patient to receive chyle by the intravenous route and the first so treated to survive. Peet[34] in 1943 was the first to inject chyle into the sternum. It was as recent as 1946 that Lampson (Meade and associates[31]) proved that the condition could be cured by ligation of the duct in the chest. From 1946 to 1951, five cases of transthoracic duct ligation were reported by Shumacker.[37]

SCIENTIFIC BACKGROUND

Anatomy.—Anatomists mention practically nothing concerning the cross-sectional dimensions of the duct or its lumen. Cunningham[13] stated that the total length of the duct averages about 45 cm. It is dilated at both its origin and termination. The narrowest point is usually opposite the fifth thoracic vertebra. The caliber is variable, and often the thoracic part consists of a series of anastomosing channels. The widest part is the cisterna, which may be entirely absent. Several valves are present and formed by semilunar folds of the tunica intima, arranged in pairs, and the most perfect pair is situated at or near the lymphovenous junction. Agreeing with the anatomists, Thorek[41] stated "At the level of the seventh thoracic vertebra the duct begins to cross obliquely to the left until it reaches the left side of the body about at the level of the fifth thoracic vertebra."

Histology.—The duct has been described by Bailey[30] as possessing a considerable amount of muscle tissue. The intima consists of an endothelial lining, a thin intermediate layer of fibro-elastic tissue in which are bundles of longitudinal muscle fibers, and an internal elastic membrane composed of a longitudinal network of elastic fibers. The media is the thickest coat and consists of longitudinal and circular muscle bundles, the former predominating. The adventitia is poorly defined. Near the media is a layer of coarse collagenous fibers mainly longitudinally disposed and containing considerable elastic tissue and occasional longitudinal muscle fibers. The outer layer is more finely fibrillar and merges with the surrounding areolar connective tissue.

Physiology.—In discussing the paper by Shackelford and Fisher, Penick[19] stated that valves in the duct are inefficient and that extraductal pressure could force chyle in both directions. Cummins[17] made the interesting comment that in his case the duct was collapsed to the size of a No. 30 linen thread and that after ligation the ductal diameter was that of a No. 6 catheter (English). This leads us to assume that the application of pressure against the duct caudad from a point of leakage and against a centrum may make this duct easier to delineate with or without opening the mediastinal pleura. It has been stated by Drinker and Yoffey[1] that after ligation the intraductal pressure may reach 35 mm. H_2O.

The regulatory factors affecting the flow of chyle as given by Birt[2] are as follows:

1. The vis a tergo effect depends upon the volume arising from the intestinal lymphatics.
2. There is a pressure gradient between the chest and abdomen. Inspirational negative pressure draws chyle into the chest, and the descending diaphragm increases the pressure on the abdominal lymphatics.
3. Vagal stimulation contracts the smooth muscle in the duct with a decrease in flow. Mann[6] concurred.
4. A vacuum pump effect exists in the jugular vein (we assume that Birt had in mind the side arm or Venturi principle of suction). In treatment Birt believed it logical, therefore, to induce oral starvation, administer intravenous fluids, use gastric suction to immobilize the intestines, and perhaps administer acetylcholine.

We are somewhat confused by the statement made as recently as 1952 by Berthrong and Pike that "lacerations of the thoracic duct clinically and experimentally do not result in continued chylous drainage or chylothorax—the thoracic duct has normally many collateral channels so that thrombotic occlusion of damaged vessels usually does not result in a rise of lymphatic pressure and leakage."

Bacteriology.—Birt[2] said that chyle appears to be bacteriostatic. This was suggested by Lampson in 1948. We have read of no one being able to culture any organism from chylous fluid in this clinical entity, and we were not able to do so in our case.

Pharmacology.—Birt also stated that vagal stimulation produces contraction of smooth muscle and decrease in flow of chyle through the duct (and also through a point of leakage) and that Adrenalin produces dilatation of the duct and an increase in flow.

ETIOLOGY

This variety of chylothorax has been caused by a variety of injuries, accidental and surgical. [illegible] cases have been reported as due to the following causes: [illegible] compression of the trunk,[2] contusions of the [illegible] accidents,[6] [illegible] fracture of the left clavicle and injury to [illegible] vein,[4] contusions of the chest, [illegible] fracture of the ribs,[14] gunshot wound of the chest[illegible, 36, 48], surgical traumas in general[16], after splanchnicectomy[23, 34], after surgery for tetralogy of Fallot[37, 48], after thoracoplasty with apicolysis[12], following traumatic pseudocyst of the pancreas[45], after cough[11, 26], after hyperextension of the spine[32], after heavy lifting[9], and after contusion of the back with fracture of centrums.[10] There may be associated disease causing fixation of the duct to the vertebrae and producing vulnerability. Meade[32] believed *fragility of the duct to be an important component.*

MORTALITY

In 1938, Shackelford discussed forty patients, nineteen of whom died. Florer and Ochsner[19] in 1945 wrote "Prognosis is grave since there is a 50 per cent mortality in cases in which operation has not been done, and direct surgery to repair the duct has been completely unsuccessful resulting in 100 per cent operative mortality." Schaffner and Kirkpatrick[35] stated in 1951 "Such *surgical treatment (ligation) has resulted in a marked decrease in mortality and nullifies Cushing's statement 'It can't be done.'*" Deaths have been due primarily to respiratory or cardiac embarrassment and severe malnutrition.

MORBIDITY

Tremendous amounts of nutritive fluid are lost and thoracenteses may be necessary over a protracted period of time. The patient treated by Bauersfeld[2] lost 22,275 c.c. of chyle by aspiration in sixteen days. The patient of Gordon[20] was admitted to the hospital in August, 1937; by December, 1938, *aspiration was required once each month. Felts*[18] *found it essential to tap his* patient's chest every three months, twenty months after treatment was initiated. Collapse can occur suddenly according to Wright,[9] and he advocated frequent examinations to exclude pleural effusion after crushing injuries of the chest and thoracic spine in order that such examinations may result in diagnosis before the onset of pressure symptoms.

CLINICAL COURSE

Fluid from the chest initially may be bloody in the experience of Lillie.[illegible] Typically the specific gravity is over 1.012, the fluid does not coagulate, present are microscopic fat globules soluble in ether and receptive to sudan III stain, the fat content is high, and rapid reaccumulation occurs. Lillie stated further that unless *fluid is removed*, cardiac and respiratory *embarrassment* occur. *If the wound in the duct fails to close or if collateral fails to become* established, malnutrition and emaciation supervene.

To the knowledge of Florer and Ochsner[1] a relatively asymptomatic interval exists between the trauma and the onset of marked dyspnea, pallor, cyanosis, thready pulse, and shock, and this *period averages four days.* The time lag in the *famous case of Beatty, which was due to fracture of the left clavicle and laceration of the subclavian vein, was six and one-half years.* Macnab,[illegible] one of the oft-quoted authorities, found it difficult to explain the latent period.

Lowman[1] wrote of a diagnostic triad: roentgenographic indications of a rapidly accumulating pleural effusion, low serum protein, and a falling lymphocyte count.

TREATMENT

This may be best discussed by tabulating years, writers, methods, and comments to indicate the trend.

1921 Guldmann[?] Rectal feedings and thoracenteses.

1926 Stewart and Linnert[?] Thoracenteses; made unsuccessful attempt to dissect the thoracic duct at autopsy.

1929 Andrews[?] Aspirations of chest with fatal result. Autopsy revealed rupture of duct between eleventh and twelfth thoracic vertebrae. "It is obvious that treatment is unsuccessful. Due to lack of any means for locating the point of rupture and the inaccessibility of the thoracic duct, radical surgery is highly impractical."

1931 Van Nuys[?] Aspiration. "Every puncture is a damaging factor as regards healing since restored negative pressure caused by aspiration sucks at the wound and makes healing impossible." He empirically gave high voltage x-ray therapy to the lower mediastinum and believed that such treatment helped the patient.

1934 Heppner Daily thoracentesis. Autopsy revealed interruption in the continuity of the duct with fibrosis about the ends.

1935 Elliot[?] Conservative aspiration, intravenous glucose with saline solution. "Ligation in the midthorax is almost certainly lethal. Some favor extensive thoracotomy or thoracoplasty to produce positive pressure in the pleural cavity favoring spontaneous closure of the duct."

1936 Strauss[?] (a) Desired to have fluid in the chest under pressure for tamponade effect but concluded that without fixation of the mediastinum this could not be achieved; (b) elimination of fat from the diet is important; (c) water intake should be limited; (d) there is no way of producing tamponade by air or fluid; (e) oxygen tent is of no aid when collapse occurs from mediastinal displacement due to collection of fluid in the thoracic cavity; (f) frequent aspiration is necessary to save life; and (g) there is no advantage in leaving some of the fluid. In fact partial aspiration means more frequent aspiration and every puncture adds to the risk of infection.

1937 Brown Performed posterior mediastinotomy (tenth thoracic to first lumbar vertebrae) with closed tube drainage. Patient died next day from adrenal apoplexy.

Bauersfeld First patient treated with intravenous chyle in which recovery occurred and the second reported as receiving chyle by this method.

1938 Shackelford "Believe evidence is sufficient to contraindicate feeding of fats during leakage, thus reducing intraductal pressure and through relative collapse of the vessel encouraging its repair. Surgical ligation of the duct is impractical."

1940 [illegible] "Operative repair is not feasible nor is ligation, because the patient is in poor condition and the site of rupture of the duct is rather [illegible] surgically."

1941 [illegible] Would [illegible] open external drainage of chyle unless empyema super[illegible] [illegible] should be aspirated only to relieve distress for its accumulation [illegible] probably helps to check the [illegible]

[illegible] chyle and on the fifteenth day performed a [illegible] Substituted heparin for sodium citrate as an anti[illegible] [illegible] pleural cavity to [illegible] value of [illegible] is unknown.

Peet[34] Performed ligation of the duct on the fourteenth postsplanchnicectomy day *with immediate fatality and with no satisfactory explanation of the death*

1945 Florer and Ochsner[19] Considered phrenemphraxis and pneumoperitoneum with the intent of having an elevated diaphragm occlude the rent in the duct

1947 Berry There was an associated laceration of the left lung Treatment was daily aspiration other than repair of laceration without surgery of the duct Believed surgery of the duct to be difficult and should be used only as a last resort

1949 Whitesides[45] *Performed transthoracic ligation, recommended morrhuate and fibrin foam locally*

1950 Meade[31] Believed intravenous chyle should not be used until further experimental investigation of causes of reaction has been made "One half of cases reported have recovered from aspiration alone and surgery seems unnecessary " Conduct aspiration at frequent intervals, and initiate closed *(tube) drainage if not successful One must re-expand the lung, if not possible and the leak continues, one must explore* Two weeks should be the maximum interval

1951 Auld and Needham[2] "When neurtal fat was given with Sudan III, a substantial amount of dye was recovered from the chylothorax Whereas, when equivalent amounts of fatty acid and glycerol were given (with dye) no dye was recovered in one instance and only *a small amount in another* " This *suggests feeding fatty acids and glycerol rather than a complete fat*

Schumacher[37] " A continued loss . . . *of large quantities of chyle presents a* very difficult nutritional problem For this reason it seems unwise to postpone surgical intervention until the patient's failing nutritional status makes him a poor surgical risk. . . . The duct can be ligated without harm because of the presence of collaterals "

Schaffner and Kirkpatrick[36] Recommended low surgical ligation of duct through a right thoracotomy *regardless of the location of the effusion, right or left,* and agreed in general with Meade

1952 Meade[32] "Resect a portion of the duct and ligate the ends—study the resected specimen "

Hoffman and associates[23] "Ligation of the thoracic duct in the lower third is not considered safe because collateral circulation is not as rich as in the upper *third and rupture from high intraductal pressure is brought on by acute obstruction* "

Effler[16] Discussed the disadvantages of surgery and described it as a serious undertaking stated that finding chyle leaks is a real problem, that there are anatomic variations, *that there is a deposition of fibrin and clot, and that* extensive mediastinal dissection *may convert a unilateral to a bilateral chylothorax.*

Birt[7] Utilized intravenous chyle (fresh effusion which was filtered and then heparin added) and right phrenemphraxis Declared that if effusion persisted undiminished after phrenic nerve crush that ligation should be undertaken Also mentioned that Klepser gave green coal tar dye in olive oil by duodenal tube several hours before operation *Believed that anastomosis of the duct* to a nearby vein as described by Hodge and Bridges was needlessly hazardous and difficult since simple ligation will cure

REPORT OF A CASE

A 19 year old white male soldier was stabbed over the shoulders and chest Nov 26, 1952 The following day he was admitted to a civilian hospital where the diagnosis was made Treatment included pressure bandage *to sucking wounds of the thorax and thoracenteses each* which produced 1,000 to 2,000 cc. of fluid presumed to be chyle. On Nov. 30, dyspnea and dull right chest pain appeared, chest roentgenogram revealed obliteration of the right lung hilus, and 1,500 cc. of fluid was removed.

He was admitted to the hospital at The Armored Center, Fort Knox, Ky., on Dec. 9 with obvious acute distress and dyspnea. With each cough, a large bulge appeared over the right sixth intercostal space in the posterior axillary line. Multiple small penetrating wounds were present over the back, chest, and left upper extremity. Treatment included penicillin and streptomycin, fat free diet, pressure bandage to hernia, supplemental vitamins, and daily thoracenteses. Smear and culture of the aspirated chyle were negative for bacteria. The neutral fat content was 168 mg. per cent, free fatty acid 540 mg. per cent, and cholesterol 50 mg. per cent.

Air evacuation to a chest center was contemplated. However, the rapid reaccumulation of fluid and the possible unavailability of a pressurized cabin plane led us to feel we should provide definitive care.

Fig. 1.—Posteroanterior film of chest, Dec. 10 (fourteen days postinjury).

It was determined early that nitrogen [illegible] prevailed. On Dec. 13 (eighteenth post[illegible]), exploration of the right chest was performed. Early in the morning of [illegible] a Levin tube was placed transnasally into the stomach and 240 cc. of half and half [illegible] cream [illegible] instilled; the tube was retained to permit use of dye if found [illegible]. The [illegible] parietal pleura was incised and twenty minutes was devoted to [illegible] cavity of chyle [illegible]. The intercostal hernial defect was 8 cm. [illegible] of the seventh rib. The lung was 50 [illegible] posterolateral segment of the [illegible] the lung retracted anteriorly. Milky fluid was [illegible] in the general area of the [illegible] intercostal space. The [illegible] clamp [illegible] circumferentially to allow closure of such an inverted cone with a figure-of-eight suture of 0000 silk. The loss of chyle was immediately and completely controlled in this manner without *ligation of the duct proper. It was anticipated that the tamponade effect of the* expanded and repaired lung would ensure complete success. However, a strip of Gelfoam wa

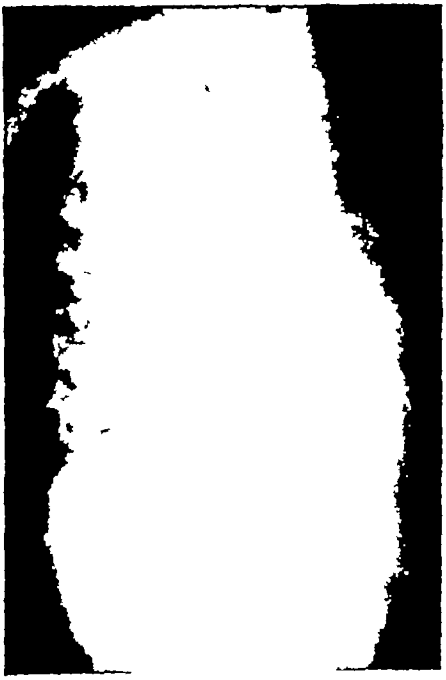


Fig. 2.—Right lateral film of chest Dec. 10

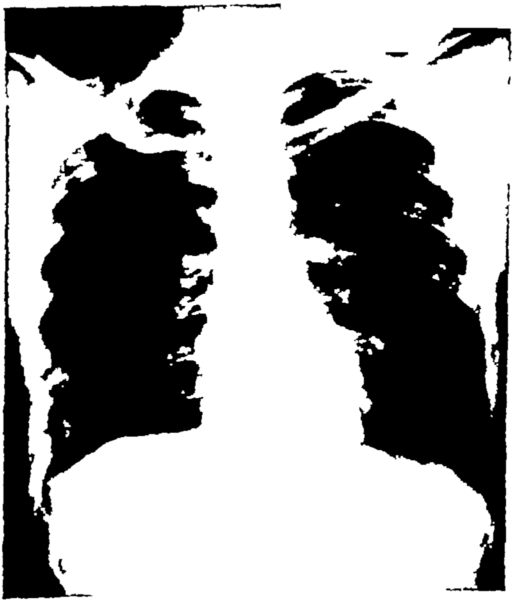


Fig. 3.—Posteroanterior film of chest Jan. 9

placed over the site of repair and the defect in the mediastinal pleura closed loosely over the strip. Each twenty minutes during the procedure, tracheobronchial tree toilet was accomplished by the anesthesiologist, saline solution was placed in the pleural cavity, and the lung was fully inflated. A thoracostomy catheter was inserted and the chest wall hernia repaired as the thorax was closed.

Recovery was uneventful. The chest roentgenograms (Figs. 1, 2, and 3) depict the situation and the early result.

DEFINITIVE SURGICAL TECHNIQUE

The actual procedure conceived and utilized at the time of surgery is illustrated in Fig. 4. Actual ligation of a pleural cone could achieve the same end product as pictured in Fig. 5.

Also offered is the possibility of using a polyethylene catheter splint and after the scarred ends of the duct are removed, fashioning a duct of mediastinal pleural flaps in the case of a long defect. The catheter could be brought out at the duct distally by a Witzel type of technique. Admittedly the thoracic duct is quite small but why could it not be repaired much as an extrahepatic biliary channel?

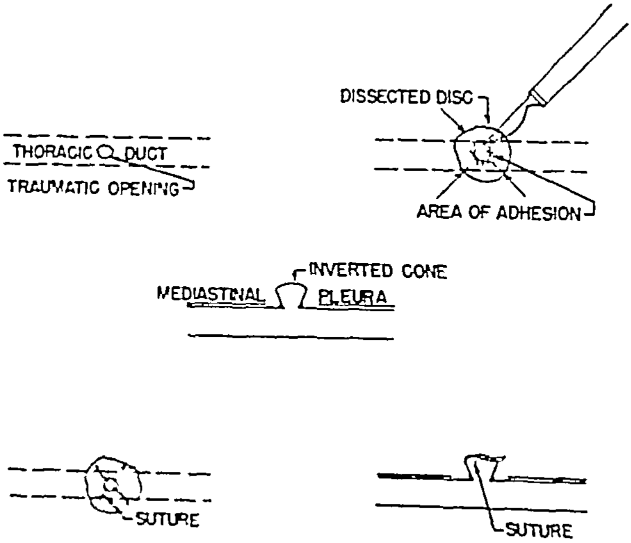
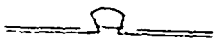


Fig. 4



LIGATION OF A PLEURAL CONE

Fig. 5

Apparently ductal ligation is relatively simple; however, we have been [illegible] impressed with the dictum of preservation of tissue including collaterals. We have learned nothing of the ability of the thoracic duct or other lymphatic [illegible]

CONCLUSIONS

1 Traumatic chylothorax should be kept in mind as a possibility in every case of pleural collection of fluid whether due to surgical or accidental trauma to the neck, the spine, the chest, or its contents

2 Daily completely evacuant thoracentesis is essential to avoid serious respiratory and cardiac embarrassment If seven days of such a regimen does not alleviate such embarrassment and leakage of chyle does not subside we believe closed (tube) drainage with applied suction should be instituted If seven days of the latter therapy does not produce definite progress we believe in exploratory thoracotomy If one is interested in preserving collaterals or is fearful of pressure rupture of the duct proximal to a ligature a plastic repair may be feasible

3 Bed rest may be considered essential to decrease the pumping action of respiration

4 Nutrition is all-important The patient should be weighed daily after thoracentesis, and intake and output faithfully recorded Oral starvation should prevail Intravenous alimentation with glucose, protein, and perhaps lipoids should cover losses Further experimentation should be carried out with intravenous chyle and with the oral combination of fatty acids and glycerol

5 The value of vagal stimulants to constrict the duct and drugs to paralyze the gastrointestinal tract, as well as gastrointestinal intubation, is questionable

6 We have endeavored to describe a simple, practical plan to follow if one is faced with the care of a patient with traumatic chylothorax and to indicate that prompt cure may be the reward for meeting the problem with boldness and simple mechanical measures

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PROTECTIVE JACKET FOR THE POSTOPERATIVE PECTUS EXCAVATUM PATIENT

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FOLLOWING radical operations for the correction of a funnel chest deformity with resultant instability of the anterior chest wall, great care must be taken to prevent injury to the thoracic viscera, particularly the heart. The patient must, of necessity, be very careful about his activity to prevent any accidental or sudden blows to the anterior chest wall. In the adult this is not particularly difficult, but in children this problem assumes great proportions. Child patients cannot be allowed to play with their friends for obvious reasons. If the child is kept in the house two to three months postoperatively there is always danger of his falling over a piece of furniture or suffering other injury which may result in damage to the anterior chest wall and heart.

This problem has been overcome to a great extent by the use of the anterior chest wall jacket shown in Fig. 1. This jacket which costs approximately $40.00 for 5- to 8-year old patients, is made of light weight plastic and fiber glass; it is adjustable and comfortable to the wearer at all times.†

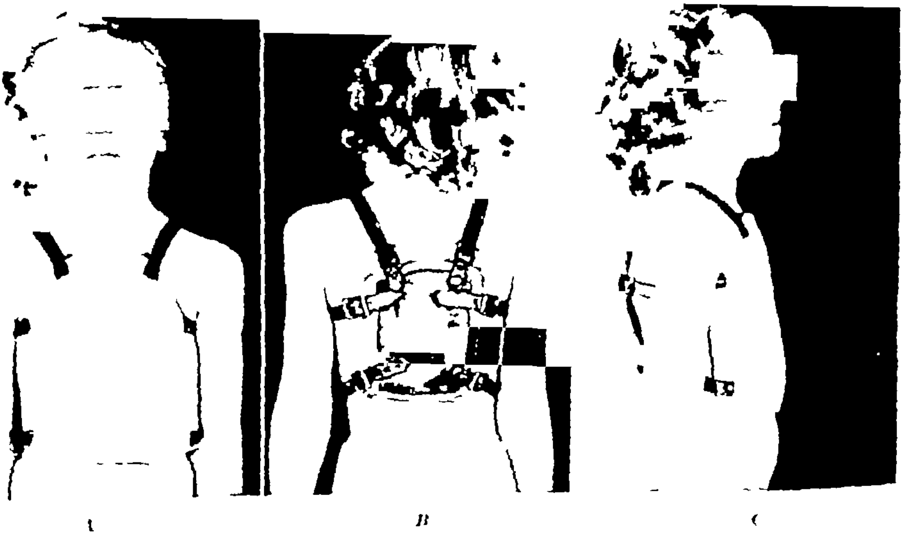

Fig. 1.—A, Anterior view. B, Posterior view. C, Lateral view.

After the jacket has served its purpose it is returned to the hospital for use on other patients. The average wearing time is approximately eight to ten weeks after operation. It is practically impossible for the patient to suffer injury to the anterior chest wall while the jacket is being worn.

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†Materials for this jacket are furnished by the Vernon Lenshoff Company, Pittsburgh 30, Pa.

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Original Communications

THE CHANGE IN THE ARTERIAL OXYGEN AND CARBON DIOXIDE TENSION DURING VOLUNTARY HYPERVENTILATION AS A TEST OF LUNG FUNCTION

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PULMONARY resection is being applied in an increasing number of cases with far advanced pulmonary tuberculosis. In order to avoid postoperative ventilatory insufficiency a new test has been used which includes the determination of the arterial oxygen and carbon dioxide tension at rest and during voluntary hyperventilation. In a group of twenty-one healthy individuals an average increase in the arterial oxygen tension of 23 ± 2.0 mm. Hg and a decrease in arterial carbon dioxide tension of 18.6 ± 2.2 mm. Hg were found. This change in the arterial tension of oxygen and carbon dioxide we believe may be regarded as an expression of the patient's respiratory reserve. The changes in the arterial oxygen and carbon dioxide tension during voluntary hyperventilation in sixty-nine patients with a varying degree of impaired respiratory reserve are reported.

METHOD

A blood sample is taken through an indwelling needle in the femoral artery. After the introduction of the needle a few minutes should be allowed so that the [illegible] is breathing quietly when the blood is drawn. A few deep breaths may [illegible] the values; however, two patients were asked to hold their [illegible] seconds but no significant change in the arterial oxygen and [illegible] observed.

[illegible] is instructed to hyperventilate as much as possible. After [illegible] seconds with the patient still hyperventilating the [illegible] taken.

[illegible]

It is of the utmost importance that the patient makes every effort to hyperventilate as much as possible Otherwise false values are obtained The patient's cooperation is as important in the hyperventilation test as when testing the maximal breathing capacity

In the immediate postoperative period the patients have too much pain to perform a good hyperventilation test The change in the arterial oxygen and carbon dioxide tension during this postoperative period is usually very small and is not an expression of the true respiratory reserve

Oxygen and carbon dioxide tensions (pO_2 and pCO_2) in the arterial blood are determined according to the method of Riley, Proemmel, and Franke Washing the capillary with physiologic saline solution has been abandoned due to the solubility of both the carbon dioxide and the oxygen in it[3] The cup is sucked out by means of a special suction line in order to have only a few units of blood covering the upper meniscus of the bubble in the capillary Then sodium hydroxide solution 4 0 per cent is filled in the syringe cup and used for both the washing down of the capillary and the carbon dioxide absorption from the bubble at the same time

To obtain some information about the accuracy of the method 41 experiments were performed in which the blood was equilibrated fifteen to twenty minutes with a known gas mixture passing through a tonometer The oxygen and carbon dioxide tension in the blood was then determined The mean difference between the oxygen tension in the blood and in the gas mixture was -1 8 mm Hg ± 0 77 As this difference is not statistically significant, the method is considered reliable

The mean difference between the carbon dioxide tension in blood and in the gas mixture was -2 37 mm Hg ± 0 59 This difference is significant which makes the values of the carbon dioxide tension less reliable

TABLE I RESTING ARTERIAL pO_2 AND pCO IN MM HG AND THE DIFFERENCE BETWEEN VALUES DURING VOLUNTARY HYPERVENTILATION AND REST (MEAN VALUES AND STANDARD DEVIATION)

GROUP	NO OF CASES	RESTING ARTERIAL pO	RESTING ARTERIAL pCO	DIFF pO HYP VENT pO REST	DIFF pCO HYP VENT pCO REST
1 Normal	21	86 0 ± 1 1	35 0 ± 1 4	+23 0 ± 2 0	-18 6 ± 2 [illegible]
2 Unilateral	35	76 8 ± 1 7	39 6 ± 1 0	+ 8 4 ± 1 7	- 4 3 ± 1 3
3 Bilateral	31	75 5 ± 1 9	38 6 ± 1 4	- 0 2 ± 1 5	+ 0 2 ± 1 5
4 Clinically bad	11	70 1 ± 3 6	39 2 ± 2 4	- 2 2 ± 2 5	+ 6 0 ± 1 7

RESULTS

The patients were divided into groups including (1) normal persons (2) patients with unilateral pulmonary tuberculosis (3) patients having bilateral pulmonary tuberculosis and (4) patients who were clinically very poor risks

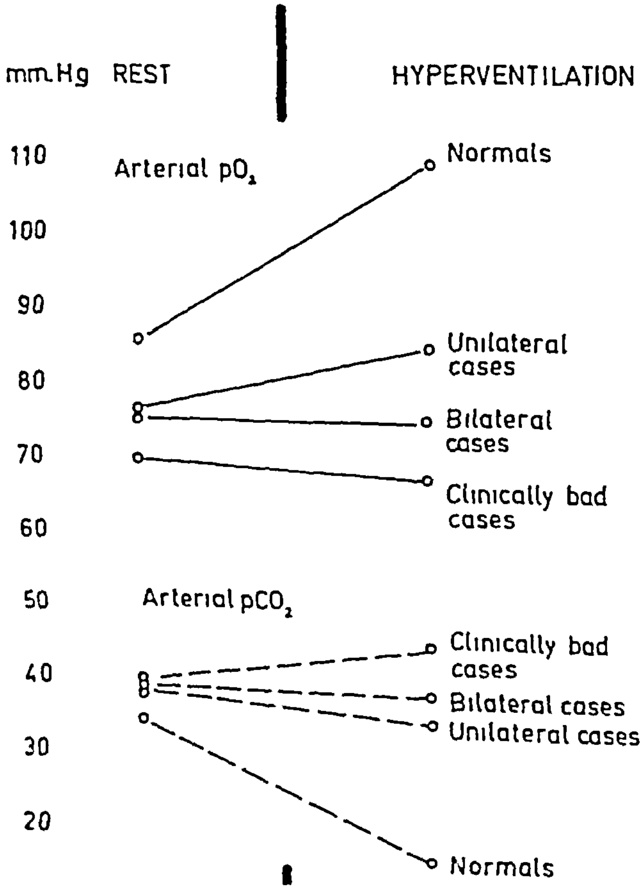
A resection was planned or performed for all individuals in Groups 2 to 4 The results are shown in Table I and Fig 1

Group 1—Normals

Group 2.—Patients with unilateral pulmonary tuberculosis needing resection have a much lower ability to increase the arterial pO_2 and decrease the arterial pCO_2 than normal individuals.

Group 3.—In patients with bilateral pulmonary tuberculosis who needed resections there was no ability to increase the arterial pO_2 and decrease the arterial pCO_2. There was on the contrary in several instances a decrease in arterial pO_2 and an accumulation of carbon dioxide during the voluntary hyperventilation.

It is evident that Groups 2 and 3 include patients with a wide range of pulmonary reserve.



[illegible] the changes in arterial pO_2 and pCO_2 during voluntary hyperventilation [illegible] with varying [illegible] pulmonary reserve.

[illegible] the material is divided according to the amount of tissue re- [illegible] the groups are too small to show any significant difference [illegible]

Group 4.—A group of clinically very poor-risk patients was collected. It [illegible] with advanced bilateral tuberculosis and one patient who had undergone a right pneumonectomy for cancer one year previously. All these patients could walk on a horizontal plane but had to rest after walking only one flight of stairs. The maximal breathing capacity varied between 24 and 68 L., the average was 46 L. per minute. In this group there was no increase of arterial pO_2 and there was a carbon dioxide accumulation during voluntary hyperventilation. Ten survived the resection. One patient died eight days after an extrapleural pneumonectomy. Autopsy showed cor pulmonale.

Of the ten remaining, seven are respiratory cripples and unable to work. Three patients are working. Of these, one patient is a respiratory cripple but still performs full time work as a construction engineer. Ten years ago he had a left seven-rib thoracoplasty performed and there is now a big residual cavity in the left upper lobe. Two years ago a right upper lobectomy and a five-rib thoracoplasty was performed. The right lung then had 82 per cent of the total oxygen uptake. After the resection, the patient is only able to walk slowly on a horizontal plane. Maximum breathing capacity is 28 L. per minute. Of the other two working patients, one works six hours a day as a clerk, the other is a full time laboratory nurse.

A 30 year-old patient with only a functioning left lung had normal values (during hyperventilation an increase in arterial pO_2 from 85 to 109.6 mm. Hg and a decrease in pCO_2 from 35 to 7.4).

A 61 year-old patient with only a remaining left lung was however a respiratory cripple. The arterial pO_2 decreased from 55.3 to 54.1 mm. Hg during voluntary hyperventilation, and there was an increase in the arterial pCO_2 from 40.2 to 50.4.

In one patient the left phrenic nerve was damaged during the removal of a mediastinal tumor six years earlier. The left diaphragm now made no excursions. Bronchospirometry showed 34 per cent of the total oxygen uptake and 23 per cent of the ventilation in the left lung. During voluntary hyperventilation the arterial pO_2 did not rise significantly (only from 86.9 to 87.9 mm. Hg) but there was a pronounced decrease of pCO_2 from 33.9 to 20.8 mm. Hg.

DISCUSSION

During a voluntary hyperventilation normal individuals have an ability to increase the arterial pO_2 and decrease the arterial pCO_2. This ability becomes less pronounced in cases where lung parenchyma has been destroyed and ventilation impaired. In some of the patients with far advanced pulmonary disease an abnormal reaction with a decrease of the arterial pO_2 and an accumulation of carbon dioxide has been observed during the hyperventilation. We believe that it requires more work for these patients to hyperventilate than is required for normal individuals and the corresponding gain in ventilation is insufficient. In persons with tuberculous empyema or a fixed diaphragm after bilateral pneumothoraxes the work required to hyperventilate is considerable but the increased ventilation is negligible. A decreased arterial pO_2 and a carbon dioxide accumulation may then be present.

In this group of cases with little respiratory reserve most patients will survive the operation. They are usually somewhat more crippled after the operation but they may have little or no sputum and their general condition may improve.

In this group of patients with little respiratory reserve it is important to check the arterial oxygen and carbon dioxide tension at intervals after the operation. With oxygen therapy the patient may have a good color but a pronounced carbon dioxide retention. A tracheotomy may be performed early to improve the ventilation and bring the patient through the immediate postoperative period. The dead space will diminish with approximately 100 ml after a tracheotomy and the airway may be kept clean by aspirations until the patient is strong enough to cough effectively.

SUMMARY

The arterial oxygen and carbon dioxide tension at rest and during a voluntary hyperventilation has been investigated in persons with varying degrees of respiratory insufficiency. Patients without ability to increase the arterial pO_2 and decrease the pCO_2 during hyperventilation are considered to have very poor respiratory reserve.

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THE EFFECT OF CAVERNOSTOMY ON GIANT PULMONARY CAVITIES

Report of Twenty-eight Cases

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THE opening and drainage of pulmonary tuberculous cavities is the oldest surgical procedure tried for the cure of pulmonary tuberculosis. Cases where cavernostomy was used have been reported occasionally since the seventeenth century, as Le Carboulec[1] and Elliott[2] have demonstrated. The establishment of this procedure as a treatment for pulmonary tuberculous cavities, however, is due properly to De Cerenville,[3] of Lausanne, who not only combined it with some primitive thoracoplasty, but also practiced the chemotherapeutic tamponade of cavities with gauze soaked in iodoform and other antiseptic agents.

The views of De Cerenville were later confirmed by the work of Sauerbruch[4] who showed the advantages of a preliminary thoracoplasty in cavernostomy.

The modern work of Coryllos and Ornstein[5] on the importance of draining bronchi in the treatment of cavities gave special interest to cavernostomy. It was possible to interfere directly by draining the bronchus, especially in those cases in which collapse therapy and even thoracoplasty had failed to close the cavity.

Cavernostomy was then established as a supplementary procedure for the treatment of residual cavities after thoracoplasty; the persistence of the cavities was attributed to the nonocclusion of their draining bronchus. The favorable effects of cavernostomy in the treatment of residual cavities encouraged further research especially after the discovery of the antibiotics. O'Brien[6] and Bernou and their respective associates and Bonniot and Joly[8] also applied the procedure in instances of giant cavities without any previous thoracoplasty, with hopeful results.

The favorable results of the continuing research induced Maurer of Davos to try to substitute cavernostomy, in many cases, for surgical collapse therapy; he increased the indications for its application, since with his own bloodless procedure physicians not specializing in surgery then would be able to practice it.

Maurer's[9, 10] technique consists of catheterization of the cavity, widening of the chest wall sinus by means of laminaria, tamponade with gauze soaked in antibiotics and finally closure of the cavity's draining bronchi by means of diathermocoagulation.

As Maurer's published results seemed to be more than satisfactory, naturally we were also interested in the application of the procedure to patients with giant pulmonary cavities who, for various reasons, could not be subjected to other effective treatment.

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In the application of cavernostomy in our cases we followed a technique more simple than Maurer's. First we performed the catheterization according to Monaldi's method, then we widened the chest wall sinus by removing and inserting rubber drainage tubes of progressively increasing diameters. In this way we were able to obtain a progressive widening of the sinus without the use of laminaria sticks, which protected the patient from undesirable reactions. The final stage in the procedure was the chemotherapeutic gauze tamponade; if necessary, cauterization of the open draining bronchi was performed.

TABLE I

	NO. OF CASES	CLOSURE OF CAVITY OBLITERATION OF DRAINING BRONCHUS	SHRINKING OF CAVITY OPEN DRAINING BRONCHUS	WITHOUT EFFECT	ACCENTUATION
Sex					
Male	9	[illegible]	2	–	1
Female	19	4	8	4	
Total	28	10	10	4	4
Age (in years)					
[illegible]	10		[illegible]	2	2
[illegible]	15	5	7	2	1
[illegible]		2	0	–	1
Total	28	10	10	4	4
Duration of disease before operation					
[illegible]	4		0	1	–
[illegible]	11	[illegible]	5	1	2
More than [illegible] years	1	4	5	2	2
Total	28	10	10	4	4
Extent of disease before operation					
[illegible]	12	–	[illegible]	–	1
[illegible]	16	[illegible]	[illegible]	[illegible]	[illegible]
Total	28	[illegible]	10	4	4
[illegible]					
[illegible]	[illegible]	[illegible]	[illegible]	–	1
[illegible]		1	1	1	–
[illegible]	–	1	–		1
[illegible]	[illegible]	1	4		–
[illegible]	[illegible]	1	1		–
[illegible]	28	10	10	[illegible]	[illegible]

RESULTS

[illegible] In all cases streptomycin PAS [illegible] Table I [illegible] of cavernostomy connected with the sex and age of the patient, chronicity and extent of the disease as well as the *anatomic and pathologic alterations*.

The roentgenographic disappearance of the cavity alone must not be considered as a complete therapeutic result, *the disappearance must be followed by the permanent obstruction of the draining bronchi*.

The cases in which shrinking of the cavity was marked but no obstruction *of the draining bronchi* was obtained were considered only improved. Their treatment must be completed with thoracoplasty if this is possible.

Cases which, during a period of at least six months, did not present any change from the application of cavernostomy were classified as without effect while the cases in which, after the institution or during the time of cavernostomy clinical and focal aggravation were noted were reported as aggravated.

The possibility of favorable results seems to be better in men than in women. To explain this phenomenon the neurovegetative inconstancy generally observed in women must be taken into consideration, because of it women tolerate the continued and long-sustained irritation caused by cavernostomy with greater difficulty. It seems that there is no essential difference among the three categories of age mentioned in Table I however, from the fact that the *shrinking of the cavity presupposes a preserved elasticity of the pulmonary* tissue, to a sufficient degree it is understood that, from this point of view, an advanced age brings forth difficulties regarding the favorable influence of the cavernostomy. The difference in the percentage of the favorable effects obtained in the various categories described in Table I and connected with the period of the disease before the institution of cavernostomy must also be attributed to the same reason. The longer the period of disease before the institution of cavernostomy the greater the presupposition of a sclerosis of pulmonary tissue as well as of the wall cavity, this of course, renders difficult the attainment of the complete shrinking closure of a cavity.

The extent of the disease plays an important part in the effects obtained by *cavernostomy*. In cases of slowly progressing tuberculosis, *the possibility of success in catheterized cavities* reached 58 per cent, while in a progressive form of the disease the percentage hardly amounts to 18 per cent. The greater possibility of success *in catheterized cavities therefore, is found in unilateral* tuberculosis with a single cavity and the possibility decreases progressively in the other categories. In Table II the results of cavernostomy are given analytically, the *localization of the cavity, its size the condition of the pulmonary* tissue around the cavity and finally the duration of the cavernostomy in each case are also included.

The greatest *rate of cure is observed in cavities localized in the medium* and lower parts of the lung while *in the cavities of the upper part the percentage* evidently diminishes. This may be attributed first to the lack of sufficient healthy pulmonary *tissue around the cavities of the upper region and second* to the existence of extended adhesions between the cavities and the thoracic wall. The cavities located in the medium and lower regions of the lung are mostly free of adhesions.

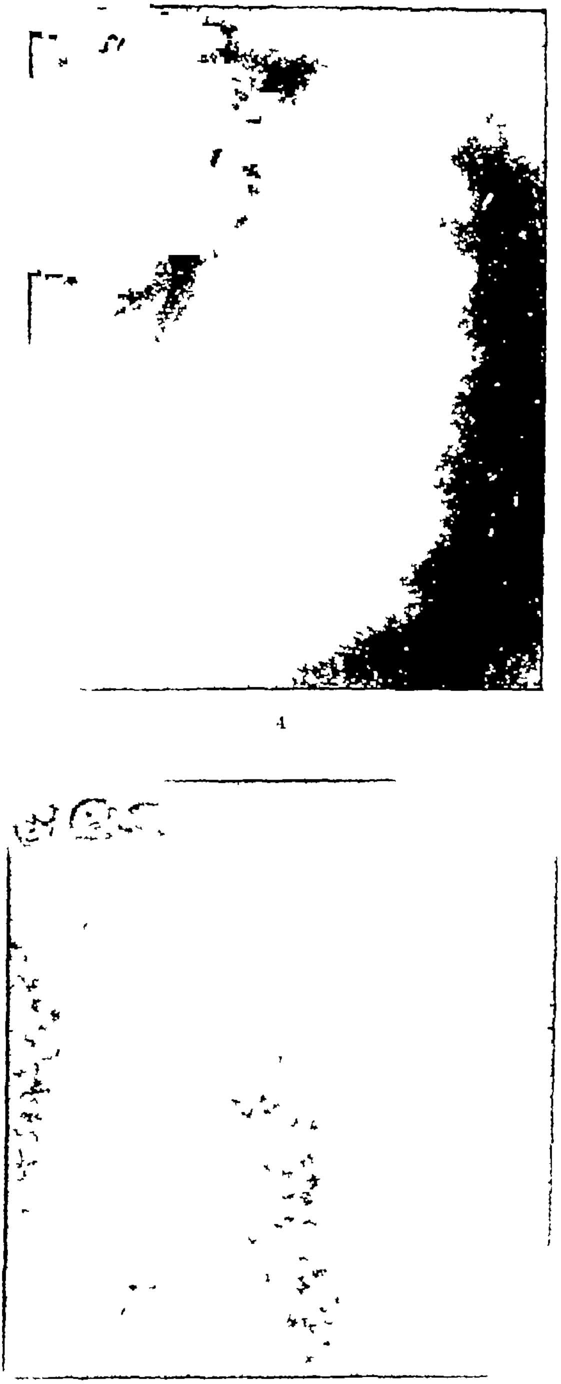
The size of the cavity does not seem to influence the therapeutic effect. The percentage of favorable results is about the same in the two categories of Table II. We must point out, however, that the size of the cavities in our cases is not caused solely by the ravage of pulmonary tissue but depends considerably upon its tension caused by the check-valve mechanism function of their draining bronchi.

TABLE II

	NO. OF CASES	CLOSURE OF CAVITY, OBLITERATION OF DRAINING BRONCHUS	SHRINKING OF CAVITY, OPEN DRAINING BRONCHUS	WITHOUT EFFECT	ACCELERATION
Localization of cavity					
Upper region	25	7	10	4	4
Medium region	1	1	–	–	–
Lower region	2	2	–	–	–
Total	28	10	10	4	4
Size of cavity (in cm.)					
4 to 7	21	7	8	3	3
8 to 11	7	3	2	1	1
Total	28	10	10	4	4
Duration of cavernostomy (in months)					
2 to 6	7	3	–	1	3
7 to 12	7	4	1	2	–
12 to 25	14	[illegible]	9	1	1
Total	28	10	10	4	4
Around cavity pneumonic tissue					
Healthy	15	8	6	–	1
Changed	13	2	4	4	3
Total	28	10	10	4	4

The condition of the lung tissue surrounding the cavities seems to influence essentially the therapeutic effect, as can be observed in Table II. In those cases in which the cavities were surrounded by a healthy pulmonary tissue the percentage of cure amounted to 53 per cent; in cases with the tissue affected either by a tuberculous process or sclerosis the percentage scarcely reached 15 per cent. The duration of the cavernostomy cure in our cases was two to twenty-five months. Within two months aggravation and death occurred in three cases. In the other cases the minimum cure time was six months; cure time which lasted more than twelve months concerns cases in which the occlusion of the draining bronchi [illegible] difficult because of extensive alterations and hardening of the [illegible]. There were ten cases in which closing of the cavity and permanent occlusion of the draining bronchi occurred; this was 36 per cent of the total number of cases. The [illegible] patients in this group left the sanatorium and went back to their [illegible]

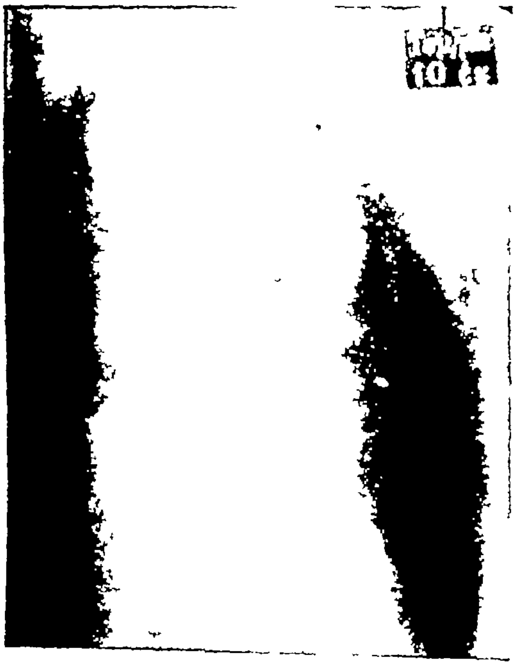
[illegible] the cavernostomy [illegible] cases [illegible] year [illegible] two cases one year [illegible] and for two cases [illegible] months. In all these

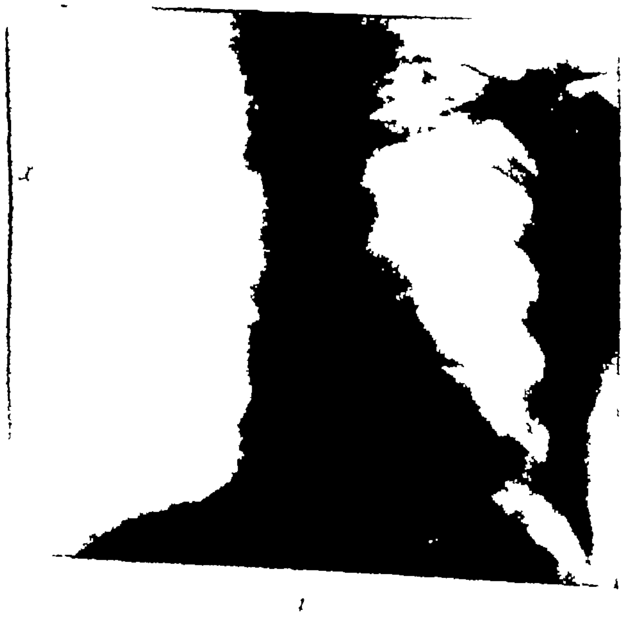


A

B

Fig. 1.—A, Giant cavity occupying the upper third of right lung. B, Twenty-five months after the removal of the catheter. No evidence of cavity.





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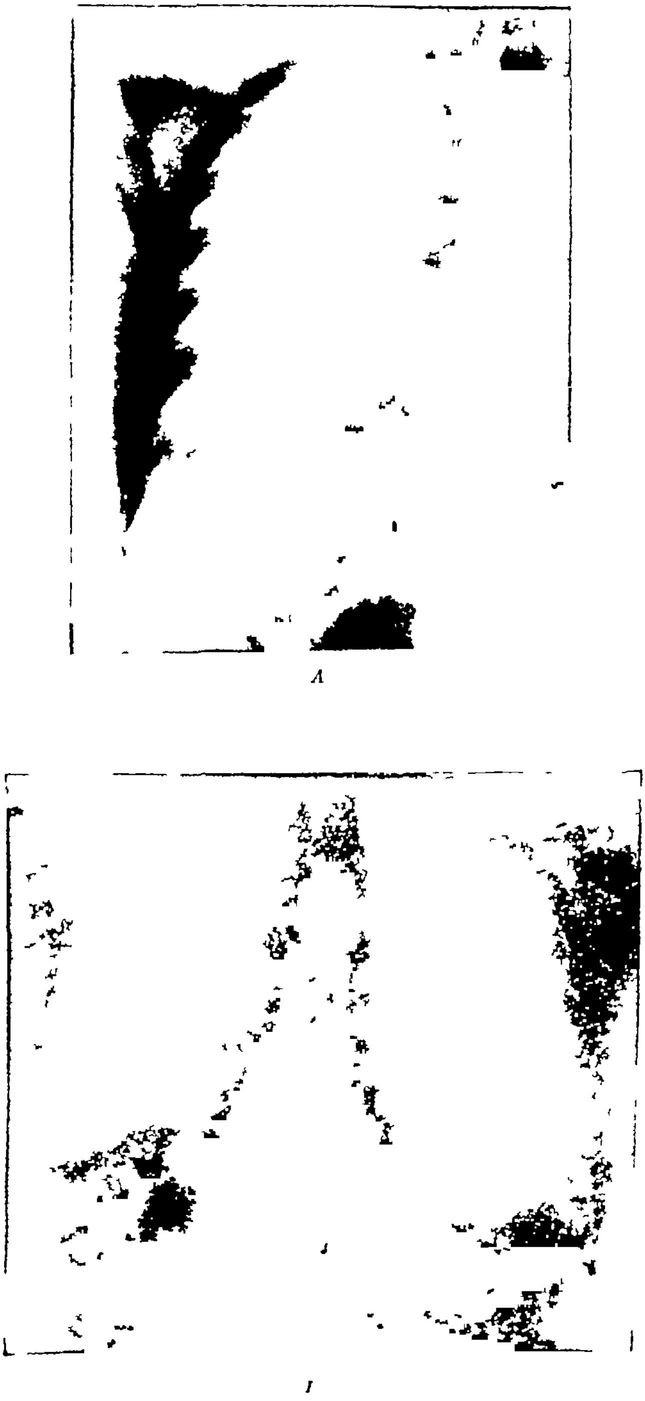

Fig. 3.—A, Giant cavity occupying lower third of right lung. B, Twelve months after the removal of the catheter. No evidence of cavity.

cases the expectoration was continuously negative for tubercle bacilli and the consequent roentgenologic control showed stability of the favorable result obtained.

The cases with shrinking of the cavity but with nonocclusion of the draining bronchi amounted to ten, that is, approximately 36 per cent.

In two of the previously mentioned cases supplementary thoracoplasty was applied and in one a successful lobectomy; in the remaining seven cases at present any supplementary intervention is impossible.

The cases without effect and those aggravated amount to 28 per cent of the total; in all these unsuccessful cases the patient died in two to eighteen months from the institution of the cavernostomy, some of them because of the nonarrest of the progression of the tuberculous process and others because of the aggravation caused by the intervention.

SUMMARY

The results of twenty-eight cases with giant cavities to which cavernostomy was applied following Maurer's technique are presented: complete and permanent cavity closure and occlusion of the draining bronchi, 36 per cent; shrinking of the cavity without occlusion of the draining bronchi, 36 per cent; no shrinking whatever or aggravation, 28 per cent.

The contribution of the various factors connected with the constitution, clinical evolution, pathologic and anatomic form and localization of alterations as regards the favorable or unfavorable effects of the cavernostomy is shown in the two tables.

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EXPERIMENTAL RECONSTRUCTIVE SURGERY OF THE TRACHEA

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WITH the advancement of modern surgical techniques, anesthesia, and pre and postoperative management, surgical reconstruction of the air passages is of more importance now, especially since there are a great number of pathologic processes in which it can be applied, such as benign and malignant tumors, stenosis, traumas, fistulas, and extrinsic and intrinsic compressions.

The experimental work carried out in animals has also been a decisive influence on the advancement of surgical techniques so that at the present time it is possible to predict the outcome of repairing either the trachea or bronchi, anastomosing the air passages, and reconstructing previously created defects with the use of plastic material and grafts.

Ferrari and Gardenghi,[1] in 1948, reported the successful resuture of the trachea after resecting a benign fibroadenohemangioma. Belsey[2] in two cases of malignant tumors of the trachea, used a stainless steel wire mesh surrounded by a free graft of fascia to repair the defect created after resecting the tumor. In 1951 Mathey[3] reported the case of a tumor at the bifurcation of the trachea in which he performed a wide resection and reconstruction using a stainless steel wire for the sutures without producing stenosis. Evans[4] repaired a large defect originated by the resection of a benign tumor of the trachea with a stainless steel wire mesh covered with a skin graft.

Cotton and Penido[5] reported the successful resection of almost all of the trachea in two patients with carcinoma after which reconstruction was possible by means of a stainless steel tube. Cahan[6] reported the case of a carcinoma of the lower third of the trachea in which excision was followed by repair with a tantalum gauze fascia lata graft; sixteen months afterward the patient was living and had no complaints. Metras and associates[7] performed a bronchotomy followed by anastomosis, in a case of adenoma. Kergin[8] after resecting a carcinoma of the intrathoracic trachea, covered the defect with a portion of pericardium; later on, due to extension of the tumor, he performed a right pneumonectomy using a portion of the right bronchus to cover the defect. Goldman,[9] in 1952, reported five cases of transpleural bronchotomy. Gebauer,[10, 11] in 1950 reported the use of a stainless steel wire mesh covered with a dermal graft in repairing the defect produced by resecting a portion of the wall of the main bronchi in cases of tuberculous bronchostenosis and also in repairing the trachea in cases of stenosis. Paulson[12] reported having used skin grafts to repair large defects in the trachea and bronchi also in cases of tuberculous stenosis. Mathey[3] using Gebauer's technique was successful in repairing one of the main bronchi also in a case of tuberculous

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bronchostenosis. Harrison[14] in 1936 reported the repair of the traumatic type of stenosis of the trachea by skin grafting. Griffiths[1] performed an end-to-end anastomosis after resecting a fractured cartilage in one of the main bronchi. Fletcher reports an accidental section and successful resuture of a bronchus using a fragment of intercostal muscle to cover the repair; bronchoscopy later on showed a slight degree of stenosis. Mathey and Oustrières[5] performed an end-to-end bronchial anastomosis covered with a skin graft after an accidental division of the main stem bronchus. Scanell[18] reported the case of a ruptured bronchus following a closed injury to the chest treated by immediate thoracotomy and repair. Levit[19] in 1912 reported the use of a free graft of fascia lata in repairing old fistulas in the air passages. Neuhof reported the successful closure of old tracheotomies also using free grafts of fascia lata. Brea, like many others, has reported successful resuture after removing foreign bodies from the bronchi. Sloan and Cowley reported a case of a posterior mediastinal tracheotomy in a case of extrinsic compression due to an aortic aneurysm.

MATERIAL AND METHODS

For this study we used the dog in our experiments.

The dog is placed on the operating table with the neck extended and under surgical anesthesia with pentobarbital. To expose the trachea an incision is made over the anterior portion of the neck at the midline from the thyroid cartilage to the base of the neck. The trachea is next dissected cleanly down an approximately 10 cm., after which the surgical procedure of choice in each of the groups which will be described is carried out. The neck is then closed by interrupted silk sutures.

Altogether we used fifty dogs grouped as follows:

1. Section and end-to-end anastomosis.
2. Homotopic autografts.
3. Homotopic homografts.
4. Heterotopic autografts.
5. Platelike heterotopic grafts.

Section and End-to-end Anastomosis (Fifteen Cases).—In five of the cases end-to-end anastomosis with interrupted silk sutures was performed, and [illegible] cases the anastomosis was performed with sutures in [illegible]

In [illegible] cases a portion of the trachea was excised and an end-to-end [illegible] silk sutures [illegible] was performed. In seven similar cases we [illegible] steel [illegible] for the sutures, and in the last case the section was [illegible] stainless steel wire for the sutures.

A[illegible] compared [illegible] three and six weeks after the [illegible]

H[illegible] [illegible] A portion of the trachea was ex[illegible] [illegible] The [illegible] was marked [illegible] sutures. In three cases, excision was made of a portion of the trachea leaving the posterior intercartilaginous membrane in situ replacing the excised portion after a few minutes with three stainless steel wire sutures in U. All the dogs in this group were sacrificed six weeks after the operation. In two cases the posterior intercartilaginous ligament was sectioned, leaving the trachea untouched. The dogs were sacrificed six weeks afterward.

Homotopic Homografts (Fifteen Cases).—In this group we used homotopic homografts, either fresh performing two operations simultaneously, or using material kept in different types of media. In two cases the graft had been kept in alcohol, the end-to-end anastomosis was done with intermittent silk sutures and the animals died thirty and forty days after the operation. In five cases the grafting was done simultaneously from one dog to the other using two stainless steel wire sutures and three intermittent silk sutures. All of the animals in this group died between the first and the seventh day after the operation. In four cases, the graft was kept in normal saline solution with penicillin and streptomycin; again in this group all of the animals died between five and thirty days after the operation. In three cases we used a lyophilized graft rehydrated by placing it in normal saline solution; the anastomosis was performed with two stainless steel wire sutures in U and several intermittent silk sutures; the animals in this group died between ten and forty-two days afterward.

Heterotopic Autografts (Four Cases).—In this group the graft was prepared by removing a portion of the cartilaginous part of the ear of the same animal which was placed around the previously resected portion of the trachea with three stainless steel wire sutures in U reinforcing the suture line with several intermittent silk sutures. The animals in this group died from two to three days after the operation.

Platelike Heterotopic Grafts (Four Cases).—A small window (1 cm. in size) was made in the anterior portion of the trachea after which a fragment of the cartilaginous portion of the ear of the dog slightly larger than the window was sutured using intermittent silk sutures over the previously created defect. The animals in this group were sacrificed 15, 20, 35, and 50 days, respectively, after the operation.

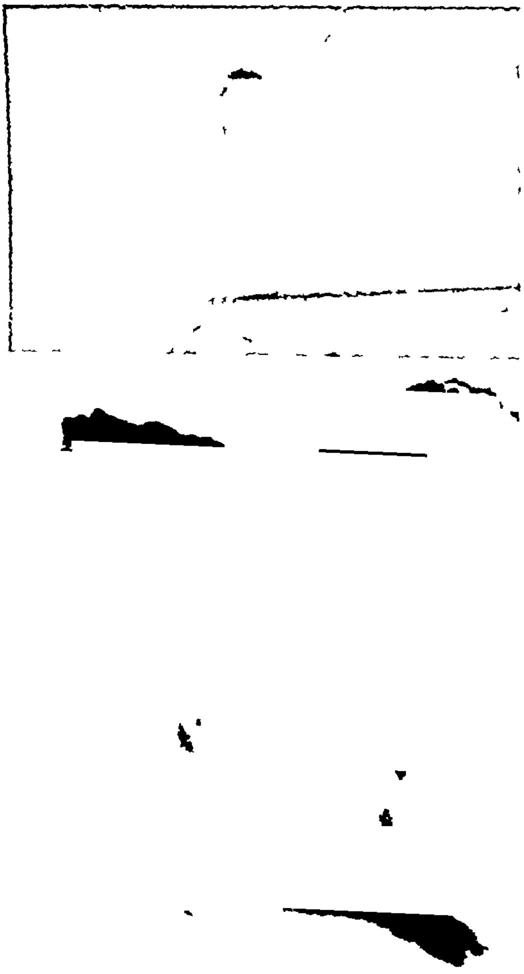
RESULTS

In all the cases a macroscopic and microscopic study was made immediately after the animal died or was sacrificed with particular emphasis on the state of the suture line, degree of epithelization, and the state of the tracheal cartilages both from the grafts and the receptor. The results of these studies can be summarized as follows:

1. Section and end-to-end anastomosis. In all those cases in which silk was used for the sutures there was stenosis to complete obstruction (Fig. 1). The microscopic study revealed loss of the mucous membrane at the suture line with infiltration by lymphocytes, polymorphonuclears and plasma cells, evidence of an intense inflammatory type of reaction.

In all those cases in which stainless steel wire was used for the sutures there was no stenosis (Fig. 2); with the exception of one case there were no evidences of inflammatory reaction or destruction of the material used for the sutures; the microscopic study revealed formation of new mucosa at the level of the suture line, the scar tissue being formed with fibrous tissue and an occasional residual inflammatory type of cell.

Fig. 1



[illegible]

[illegible] In all [illegible] in which [illegible] was used for the [illegible]

Fig. 3

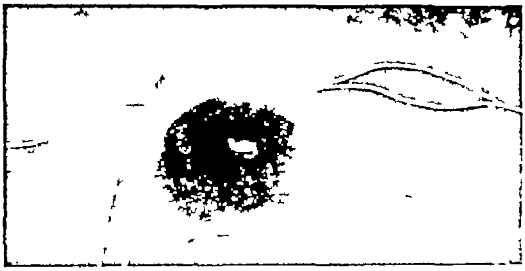


Fig. 4

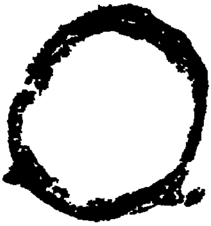


Fig. 5

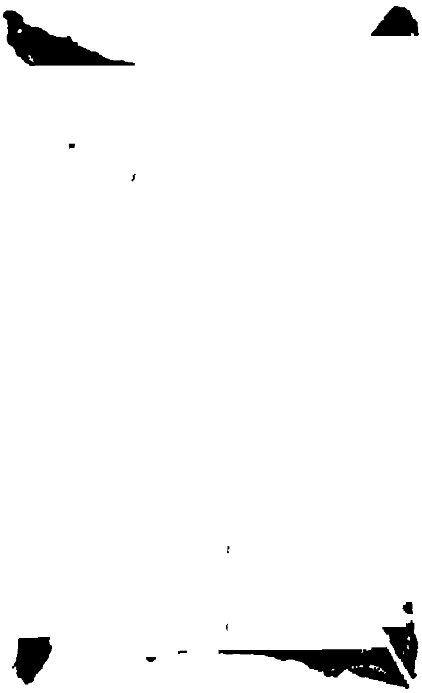


Fig. 3.—Homograft showing a complete stenosis.
Fig. 4.—Autograft with stainless steel wire sutures. Notice absence of stenosis.
Fig. 5.—Autograft with stainless steel wire suture. Notice both suture lines.

type of reaction around the trachea and in some cases pus formation. Microscopically there was necrosis at the site of the graft and a great amount of granulation tissue. There was also complete loss of the mucosa and destruction of the cartilaginous tissue. In one of the cases in which stainless steel wire was used for the sutures there were no major macroscopic abnormalities (Figs. 4 and 5). The microscopic study showed the presence of scar tissue at the suture line, complete epithelization at the inner surface, absence of inflammatory reaction, and partial ossification of the tracheal cartilage. In the remaining two cases there was a severe degree of stenosis in an hourglass fashion with superimposed infection; the microscopic study showed that the graft had been replaced by fibrous tissue with no evidences of new cartilage formation. There was also loss of the mucosa and in one of the cases squamous metaplasia.

When the trachea had been excised leaving the posterior longitudinal ligament untouched there was no stenosis and microscopically there was formation of new mucosa, presence of fibrous tissue and mucous glands. Similar results were obtained in the two cases in which the posterior longitudinal ligament had been excised leaving the trachea untouched.

[illegible]

He[illegible] In [illegible] in which silk was used to [illegible] revealed [illegible] complete replacement of the [illegible] destruction of the graft (Fig 6), microscopically there was replacement of the graft by fibrous tissue showing a great number of lymphocytes, polymorphonuclear leukocytes, loss of epithelial tissue, and destruction of cartilaginous tissue In four cases in which the graft had been preserved in normal saline solution (with penicillin and streptomycin), there was stenosis in three and destruction in one The microscopic study showed loss of the normal structure of the trachea with a few degenerated cartilages, foreign body reaction, pus formation, and squamous metaplasia of the mucosa In the three cases in which a lyophilized graft had been used, there was a severe degree of stenosis with fibrous and inflammatory type of tissues

4 Heterotopic autografts (Fig 7) the macroscopic specimens in three of the cases showed a complete destruction of the graft with superimposed infection (Figs 8 and 9) The microscopic study showed a great number of leukocytes, predominantly lymphocytes at both ends of the suture lines, together with some areas of necrosis, the other dog, which died one day after the operation, showed the graft to be collapsed, and although the histologic picture seemed to be normal, there was a great number of dilated vessels and necrotic foci

5 Platelike Heterotopic Grafts There was no stenosis in any of the specimens obtained at necropsy (Fig 10) there was a number of firm adhesions between the site of the graft and the peritracheal tissues and microscopic degeneration of the cartilaginous platelike graft which was covered with fibrous and inflammatory tissue which was found to be less, the more the time between the operation and the study The inner surface of the trachea was found to be also more epithelized in those cases which were sacrificed later on in the course of these studies

DISCUSSION

The results obtained in the first group show that the silk sutures were not sufficiently strong to maintain both ends of the anastomosed tracheal cartilages together thus the retractile power of the trachea and the superimposed infection since it is a septic air passage induced the destruction of the suture line at the time new granulation tissue had been formed which in turn brought about the stenosis in an hourglass fashion Therefore, to keep both ends of the anastomosis together, stainless steel wire was used for the sutures with good results, even in those cases in which a portion of the trachea had been excised

The stenotic process was also found in those cases in which a homotopic autoplastic grafting was done While those cases in which silk was used for the sutures showed a severe degree of stenosis comparable with the former group in those cases in which stainless steel wire was used besides the stenotic process there was superimposed infection with the exception of one case This led us to think not only that it is necessary to keep both ends of the anastomosis together but also that both the nutritional and infectious factors played an important role in our failures since when the posterior longitudinal

Fig. 7

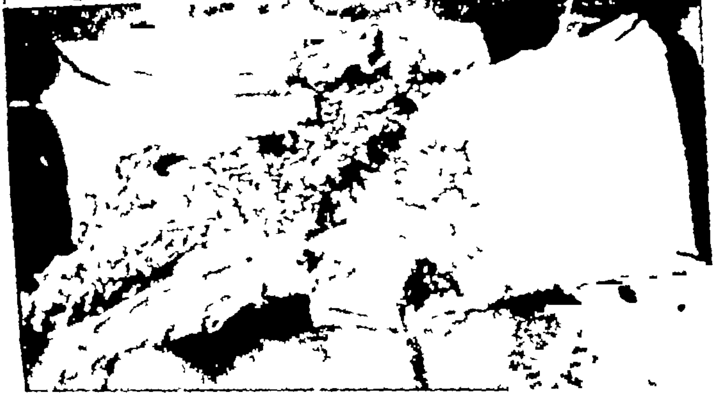


Fig. 8

Fig. 9

[illegible]

ligament was left untouched, the cases responded very well, we feel that the infectious factor is more important in producing the stenotic process

The results obtained in Group 3 show that, in some cases, besides the stenotic process, there is absorption and even complete destruction of the graft, both these reactions being a manifestation of incompatibility between graft and receptor The only tissues which are not destroyed in grafting from one animal to another of the same kind are cornea, cartilage, bone, and blood vessels In this particular case we feel that it was either a biologic type of reaction (antibody-antigen) or a special type of cellular individuality which brought about the failure in our homograft cases

In the four cases in which the graft was taken from the cartilaginous portion of the ear of the same animal (Group 5), there was also a stenotic process, this, however, was originated by a complete collapse of the graft which caused retention of secretions and clots and a concomitant superimposed infection

In the last group, both the homograft and the autograft were successful This may have been because the defect produced in the trachea was small and the graft acted only as a scaffold or, as has already been demonstrated, the cartilaginous tissue was well tolerated by the receptor

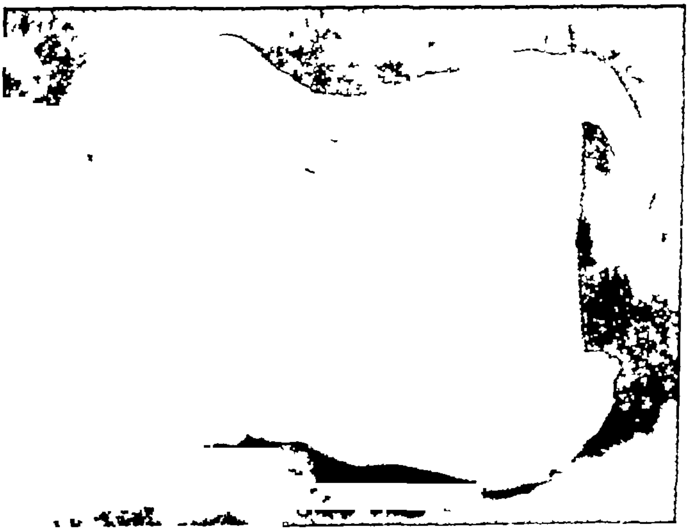


Fig 10—Inner surface of the trachea showing a platelike heterotopic graft in a homotropic autograft case

CONCLUSIONS

1 The end to end anastomosis of the trachea must be carried out using a nonabsorbable material for the sutures (such as stainless steel wire) in order to hold both ends of the anastomosis together

2 Since the air passages constitute a natural septic site the infectious factor must always be taken into consideration when surgery is performed either in the trachea or bronchi

Fig. 11

3 In the light of present knowledge, the use of either fresh or preserved homotopic homografts is not to be advised

4 It is possible to use either heterotopic autografts or homografts in repairing small defects in the trachea

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MEDIASTINAL GRANULOMAS

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MEDIASTINAL granulomas have been of increasing clinical significance since the principle of surgical exploration for indeterminate mediastinal lesions has become well established.[1-3] The majority of granulomas are cystic lesions arising from lymph nodes usually in the paratracheal region. Most of them occur as an end result of chronic granulomatous inflammation; others present a more acute granulomatous histologic reaction. In the past, the etiological basis has been assumed to be tuberculosis and the lesions have been designated "mediastinal tuberculomas." Actually the cause of most of these lesions cannot be determined accurately at the present time, and we believe that they should be designated "mediastinal granulomas."

It was Grice in 1942,[4] who reported the first excision of a mediastinal granuloma with an excellent result. Two years later Blades and Dugan[5] described another surgical case, that of a 56-year-old Army officer, and in 1948, Timmons[6] contributed the third. Samson and co-workers in 1950[7] added two cases of Paulson's to these plus four new cases of their own. That same year Peräsalo in Finland reported his case making a total of ten cases. In the discussion of the paper by Samson and co-workers, Woodruff and Goldman spoke of similar cases but these should not be included because of insufficient data. In 1951 Storey and Lyons described six more mediastinal granulomas, five of which were surgical. At about the same time Rapant and Dvoracek[10] described their case. This makes a total of sixteen mediastinal granulomas proved at thoracotomy. To our knowledge there have been no more recent reports. We wish to add sixteen cases in which operation was performed in the recent past at the Mayo Clinic and to emphasize that mediastinal granuloma represents a much more common problem than the paucity of literature would indicate.

AGE AND SEX

Mediastinal granulomas are commonly found in young adults, the average age in our series being 32 years. Eleven of the sixteen patients were between 19 and 39 years while the oldest was 59 and the youngest 2. Neither sex was favored; eight males and eight females constituted the group.

SYMPTOMS

It [illegible] is fair to state that mediastinal granulomas cause few or no [illegible] patients had no complaints referable to the chest while [illegible] symptoms. In all thirteen of these the lesions were picked [illegible] up on routinely made roentgenograms of the chest, namely, those made in general surveys, those made in Army or Navy preinduction examinations, or those made as part of a general physical checkup.

Of the other three patients, one was a 19-year-old college girl who had had four attacks of pleuritic pain associated with fever and a 6 pound loss of weight in the year prior to her clinic visit. The second was a 39-year-old housewife who had had low grade fever for four months in addition to substernal heaviness and mild exertional dyspnea for two months. The third was a 2-year-old child who had had wheezing, cough, and fever for two and one-half months.

LABORATORY DATA

The routine blood counts were within normal limits—the concentration of hemoglobin varied from 11.6 to 15 grams per 100 c.c. of blood, while the leukocyte counts were all less than 10,000 cells per cubic millimeter except for two patients who had counts of 11,200 and 12,400, respectively. The erythrocyte sedimentation rates also fell within normal range for all except one patient, mentioned previously, who had run a low-grade fever; her sedimentation rate was 48 mm. in one hour (Westergren). Differential counts and the results of urinalysis were not remarkable in any case.

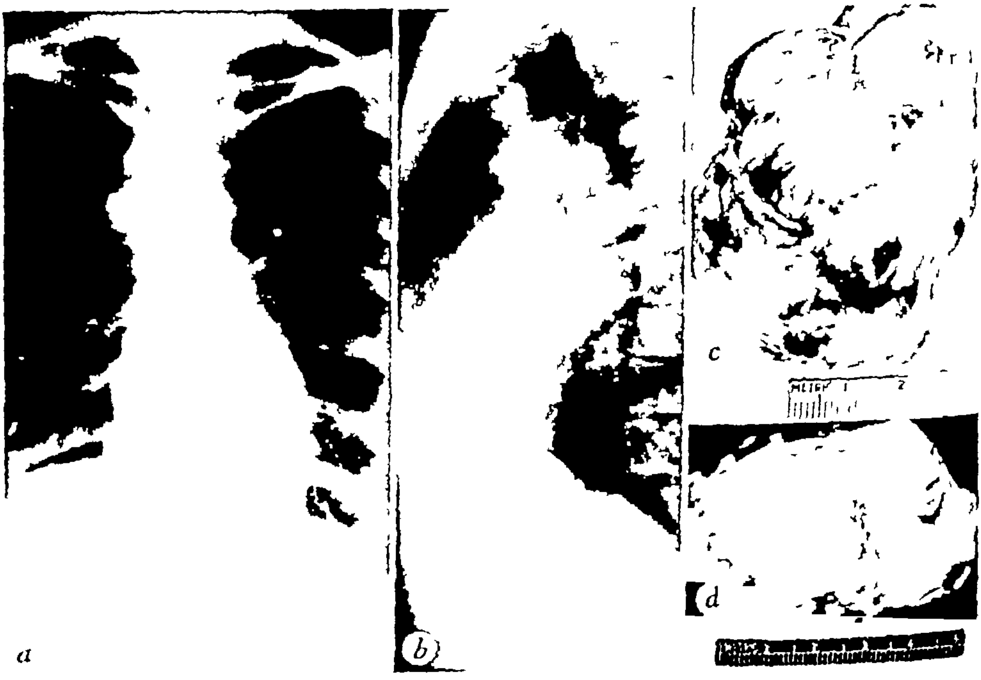


FIG. 1.—a and b, Roentgenographic appearance of a lobulated mediastinal granuloma in the right paratracheal region of a 3[illegible]-year-old woman. c, Gross specimen. d, Cut section of the specimen showing a multiloculated lesion filled with cheesy material.

RADIOLOGIC APPEARANCE AND DIFFERENTIAL DIAGNOSIS

The most common radiographic feature in our series, as in those of others, was the paratracheal location of the lesions with presentation into the right side of the thorax (Figs. 1 a and b, 3 a and b, and 4 a). In thirteen of our cases the lesion was in such a location while in the fourteenth it projected from both sides of the trachea. In the fifteenth case the tumor appeared as a poorly defined, somewhat irregular mass in the left hilus and in the remaining case the mass was in the left posteroanterior part of the mediastinum, pulling the esophagus to the left and pushing it anteriorly (Fig. 6 a and b).

In general the mediastinal granulomas were well circumscribed with an oval or a smoothly lobulated outline. Often partial calcification in the periphery was noted (Fig. 6 a and b) as the majority were cystic lesions with thin, fibrous walls. In addition some of them presented a central calcific stippled effect which, when associated with the other features, rendered the roentgenologic appearance very suggestive if not pathognomonic. It is certainly true that the preoperative diagnosis was correctly made more often in the past five years than prior to that time.

Other lesions to be considered in the differential diagnosis include thymoma, dermoid cyst, enterogenous cyst, thyroid adenoma, lymphoma, neurogenic tumor, aneurysm and other conditions of rarer occurrence.

PATHOLOGY

Grossly, eleven of the tumors were cystic lesions varying in size from that of a walnut to that of an orange (Figs. 1 c and d, 3 c and d, 4 b and 6 *inset*). The walls were usually hard but easily punctured, being composed of fibrous tissue 1 to 4 mm. in diameter. Gross calcification was often a prominent feature. At operation these cystic granulomas were found to be yellow or white and all contained a soft necrotic central mass which closely resembled wet crushed chalk or cottage cheese. Three of the specimens were solid with much cystic degeneration. The remaining two had the gross appearance of granulomatous lymph nodes [illegible] section.

Microscopically, the variation observed was consistent with the gross qualities of the lesions. The solid specimens were active granulomas that contained [illegible] small tubercles composed of palisaded epithelioid cells, central [illegible] and frequently observed peripheral foreign body cells and Langhans type giant cells. In the solid cystic variety of tumor there were [illegible] tubercles. The frankly cystic type seldom had [illegible] palisading or giant cells but had acidophilic [illegible] or simply a dense fibrous tissue (Figs. 2 and 5). [illegible] plasma cells were found in some areas but their presence was [illegible] lining portions of the walls was quite [illegible] The [illegible] was [illegible] amorphous and infrequently pre

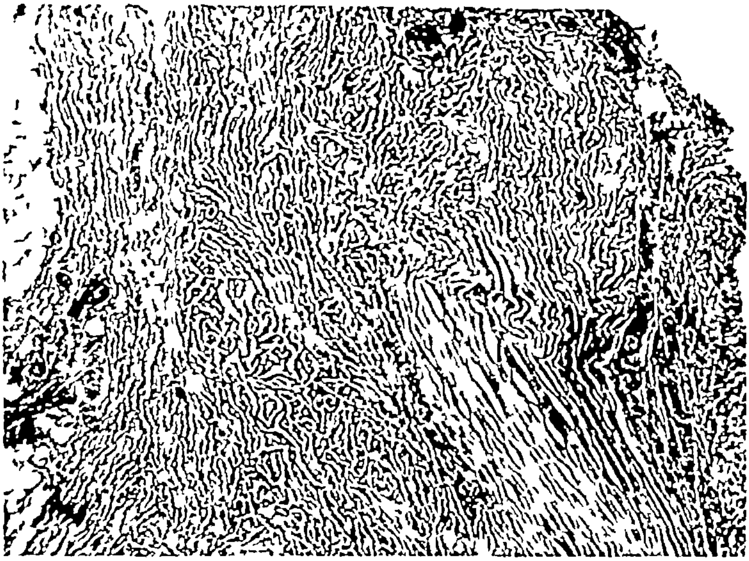


Fig. 2.—Same case as in Fig. 1. Fibrous cyst wall containing lymphocytes, plasma cells and several Langhans giant cells. On the right there is an inner rim of palisaded epithelioid cells (hematoxylin and eosin × 50).

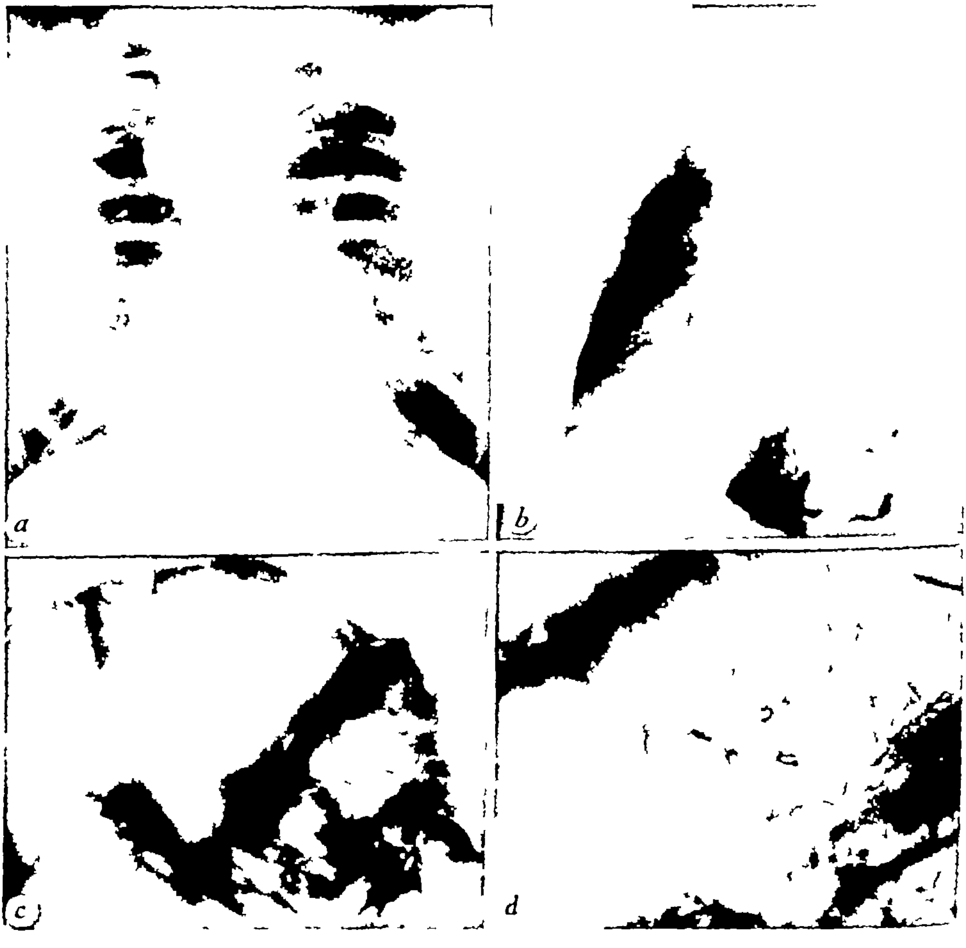
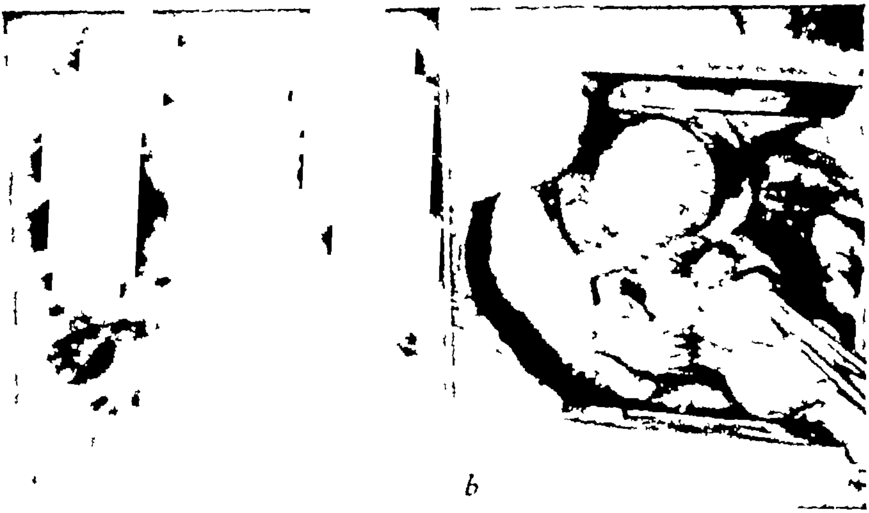


Fig. 3.—a and b, Asymptomatic typical cystic granuloma occurring in the superior mediastinum of a [illegible] year old man. c, At operation the tumor lay above the azygos vein and behind the superior vena cava and it was attached to the right lateral wall of the trachea. d, After complete excision of the tumor the bed is well exposed and the azygos vein has been

[illegible] showed no growth. In two of the cases in which no cultural studies of [illegible] were made, cultures or guinea pig inoculation of other material [illegible] bronchial secretions and pleural fluid respectively gave negative results. Tuberculin tests with old tuberculin or purified protein derivative



[illegible] Typ[illegible] [illegible] into the right [illegible] of the thorax [illegible] at [illegible] [illegible] to the [illegible] vein that the [illegible] had to be

[illegible] PPD [illegible] PPD [illegible]

Thus, there were no laboratory clues as to the etiological basis for the granuloma in any case, although we felt justified in making a presumptive diagnosis of primary tuberculosis in the child even though cultures of her bronchial secretions (the only cultures obtained) were negative for tubercle bacilli. Several skin tests for other organisms such as Histoplasma, Blastomyces, and Coccidioides were performed on three patients without significant results.

SURGICAL CONSIDERATIONS

Because of their location and adherence to adjacent structures the majority of mediastinal granulomas present difficult technical problems to the surgeon.

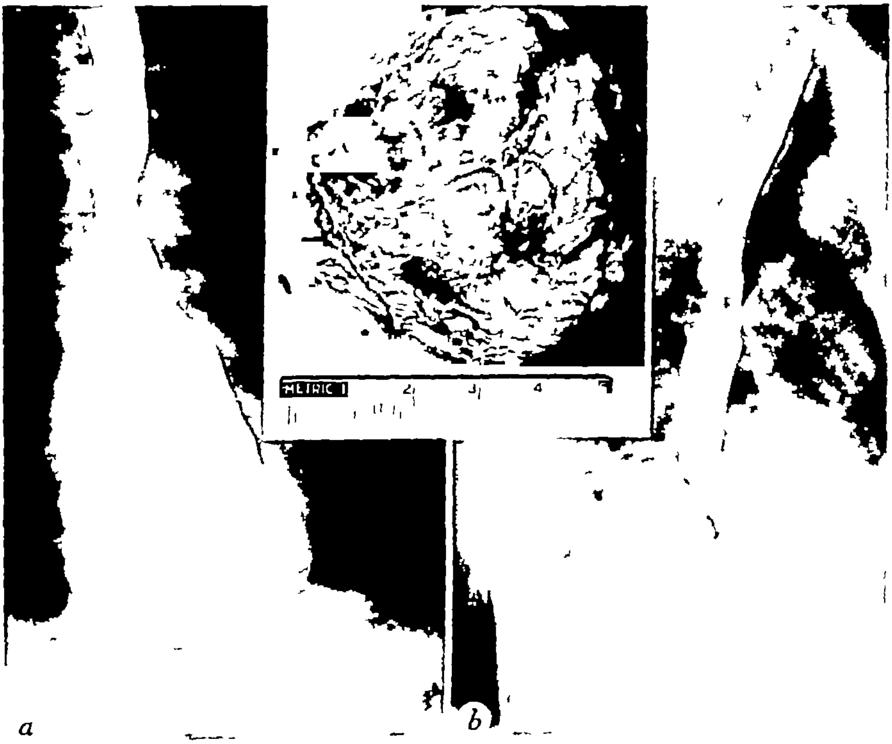


Fig. [illegible].—a and b, Barium studies showing the left lateral and forward esophageal displacement by a large asymptomatic cystic granuloma occurring in a [illegible]-year-old man. Calcification in the wall of the cyst is well demonstrated. *Inset*, Gross specimen showing the huge round cystic nature of the tumor.

They are usually quite adherent to the right lateral wall of the trachea (Fig. 3, c and d) and may extend down onto the right main bronchus. They lie posterior to the superior vena cava and either above, below, or behind the azygos vein. It is usually difficult to establish a line of cleavage between such a lesion, the trachea, and the superior vena cava. In most cases it is necessary to sacrifice the azygos vein (Fig. 4, b). Occasionally the right upper lobe is adherent to the lesion but can be separated without difficulty. Some cysts are so firmly attached to the aorta or pulmonary artery that enucleation of the clear lesion is impossible. In such a case it is recommended that the free wall be widely excised, the contents carefully evacuated, and the lining capsule curetted.[illegible]

Most granulomas, being caseous, have a characteristic white or more often yellow appearance and, when located in the right paratracheal position, present a typical picture.

In our series one death occurred as a result of technical difficulties encountered when the superior vena cava was injured and could not be repaired. In another case the patient suffered ventricular fibrillation but was revived promptly by cardiac massage. Fifteen of the sixteen patients made excellent recoveries following operation.

COMMENT

There are several controversial features of this subject. Among them is the term "tuberculoma," which previous authors have been wont to apply. We feel that this implies an etiological relationship to the tubercle bacillus. Our [illegible] discourages any certainty on this point. Even in those cases in which tubercle bacilli were reported by others, the organisms were not identified specifically. It is a well-known fact that acid-fast saprophytes are morphologically indistinguishable from *Mycobacterium tuberculosis*.[illegible] In the majority [illegible] studies were made according to strict bacteriological [illegible]. Since a specific etiological agent cannot be predicted on the evidence at hand, we feel that the nonspecific term "mediastinal granuloma" is preferable.

Of considerably more importance is the problem of indications for surgical treatment, and closely related to that is the problem of indications for resection [illegible] the type of operation. Both of these questions could be answered [illegible] the natural course of the tumor were known. Unfortunately, at [illegible] prognosis in these cases is in the realm of frank speculation. However, [illegible] to suppose that in the majority of cases the lesion [illegible] by continued fibrosis or calcification or both with [illegible] vital [illegible] structures. This assumption [illegible] relatively common yet [illegible]

[illegible] considered. [illegible] happens when spontaneous [illegible] This [illegible] occasionally in response to [illegible] could [illegible] superior vena [illegible]

The first case was that of a 27 year old woman who came to the clinic on April 19, 1939. For fourteen months she had had an intermittent but increasing cough with recent wheezing and inspiratory whistling. In addition she had coughed up some hard, round pearls (lung stones) on several occasions. Bronchoscopy revealed stenosis involving the right main bronchus at the bifurcation of the upper lobe. Repeated biopsy disclosed only inflammatory tissue. The tuberculin skin reaction had been reported elsewhere as positive. It was felt that she was suffering from enlarged, possibly tuberculous, paratracheal lymph nodes extrinsically compressing the bronchus. From 1939 through 1941, she received six separate short courses of x-ray treatment with a marked amelioration of symptoms. Bronchoscopy performed Jan. 30, 1941, still showed narrowing of the bronchus but to a lesser degree.

Except for mild exertional dyspnea the patient remained symptomatically well until September, 1949, when a constant dry cough with severe nocturnal paroxysms, a marked increase in exertional dyspnea, and an audible wheeze developed. Physical signs in November, 1949, were compatible with a right bronchial obstruction. Roentgenograms showed a mass anterior to the trachea with central calcification and constriction of both main bronchi, especially on the right. X-ray therapy was undertaken again but the symptoms became worse. Bronchoscopy on Jan. 17, 1950, showed the lumen of the right main bronchus to be one-fifth of its normal diameter while that of the left was reduced to one-third.

Exploratory thoracotomy was undertaken on Jan. 24, 1950, through a posterolateral incision over a long segment of the sixth rib. There was a dense stony hard lesion that involved the lower end of the trachea and both bronchi and extended into the region of the right pulmonary artery, the superior vena cava, and the pericardium. The mass was so hard that it was impossible to see or feel the trachea or either bronchus. A lymph node taken for biopsy was reported as calcified and inflammatory. Biopsy of the mass showed only dense hyaline fibrous tissue.

The patient made an uneventful postoperative recovery but over a period of months her wheezing, dyspnea, and cough became worse. Endoscopic dilatation elsewhere gave only temporary relief. Finally it was suggested to her local physician that a course of corticotrophin (ACTH) be given; this she began in November, 1950, continuing on a small maintenance dose thereafter. Following this there was definite improvement so that by December, 1951, she was able to be a part-time teacher. In December, 1952, she was even better, although still markedly handicapped.

The second case has been reported by others.[1] In essence it concerned a 26 year old woman who came to the clinic on Nov. 15, 1948, with a history that four years prior to that time she had had a cough, loss of weight, night sweats, and pain in the left side of the chest. These symptoms subsided on rest in a tuberculosis sanatorium although tubercle bacilli were never isolated and the tuberculin reaction was negative. In August, 1948, she began to suffer from cough, dyspnea, orthopnea, and episodes of tachycardia. During hospitalization physical signs varied from time to time but in general it was felt that there was presumptive evidence of mitral stenosis in the sharp first sound with a Grade 1 systolic murmur at the apex associated with an accentuated pulmonic second sound. Accordingly, the patient was treated by digitalization and low intake of salt. After cardiac catheterization she suddenly went into frank cardiac failure and died.

At post-mortem examination a large, gray, firm mass with the consistency of cartilage was encountered in the region of the bifurcation of the trachea. Within the mass there was a spherical lesion 1 cm. in diameter; it was yellow-gray and soft and resembled a caseous lymph node. The mass had almost completely occluded the venous return from both lungs except for the right inferior pulmonary vein, which drains the right lower lobe. The consequent pulmonary hypertension had resulted eventually in acute right ventricular failure and death. *Since there were scattered small granulomas in the lungs it was felt that the mediastinal lesion was of granulomatous origin and that during the healing process a keloidlike reaction had produced the dense collagenous mass.*

These cases illustrate the dangerous potential inherent in healing mediastinal granulomas. However, this faculty is not necessarily restricted to those found in the mediastinum. In speaking of the nature of granulomatous reaction in general, Forbus[illegible] has stated that "the healing of the lesions may give rise to effects which are as dangerous as the progressing disease."

We do not know the relationship of this entity to tuberculous mediastinal abscesses and fistulas,[illegible] since the tuberculous origin of such conditions has rarely been adequately established. This is illustrated in the following case:

A [illegible]-year-old man came to the clinic on July [illegible], 1940, with draining osteomyelitis of the sternum. He had been without symptoms until five months prior to admission when he sustained trauma to the anterior part of the chest followed by soreness and, several months later, by painful swelling. Incision and drainage had been carried out by his home physician, but when the drainage persisted for two months he came to the clinic. He was coughing up small hard "stones" about the size of wheat grains and the same material was draining from the wound. On July 27, 1940, surgical exploration of this infection which had perforated the right upper part of the sternum just at the junction of the manubrium and gladiolus was accomplished. A large pocket beneath and to the right of the sternum was unroofed and packed open. Smears of this "pus" were negative for acid-fast bacilli as were guinea pig inoculations. No "sulfur bodies" were seen. Histologic examination showed an acute granulomatous reaction with epithelioid cells, many polymorphonuclear cells and an occasional giant cell. This was interpreted as being compatible with tuberculosis. Subsequently the patient made an uneventful recovery and two years later the wound was apparently well healed.

It was the opinion of our staff at that time that the foregoing sequence of events represented a mass of tuberculous mediastinal lymph nodes which had been in the process of healing by calcification when the process was interrupted by trauma. This in turn produced a "cold abscess" and eventually a fistula. We have not included this case in the present series since the diagnosis was not established by thoracotomy, yet it illustrates another manner in which mediastinal granulomas may become complicated.

SUMMARY

Sixteen cases of mediastinal granuloma in which the diagnosis was proved by exploratory thoracotomy have been reported from one institution. This suggests that the condition is much more common than it is ordinarily thought to be. The majority of the lesions are cystic, are located in the right paratracheal region and present a rather characteristic roentgenologic appearance. All [illegible] studies in this series of cases failed to reveal a definite etiological [illegible] surgical excision of such lesions are presented.

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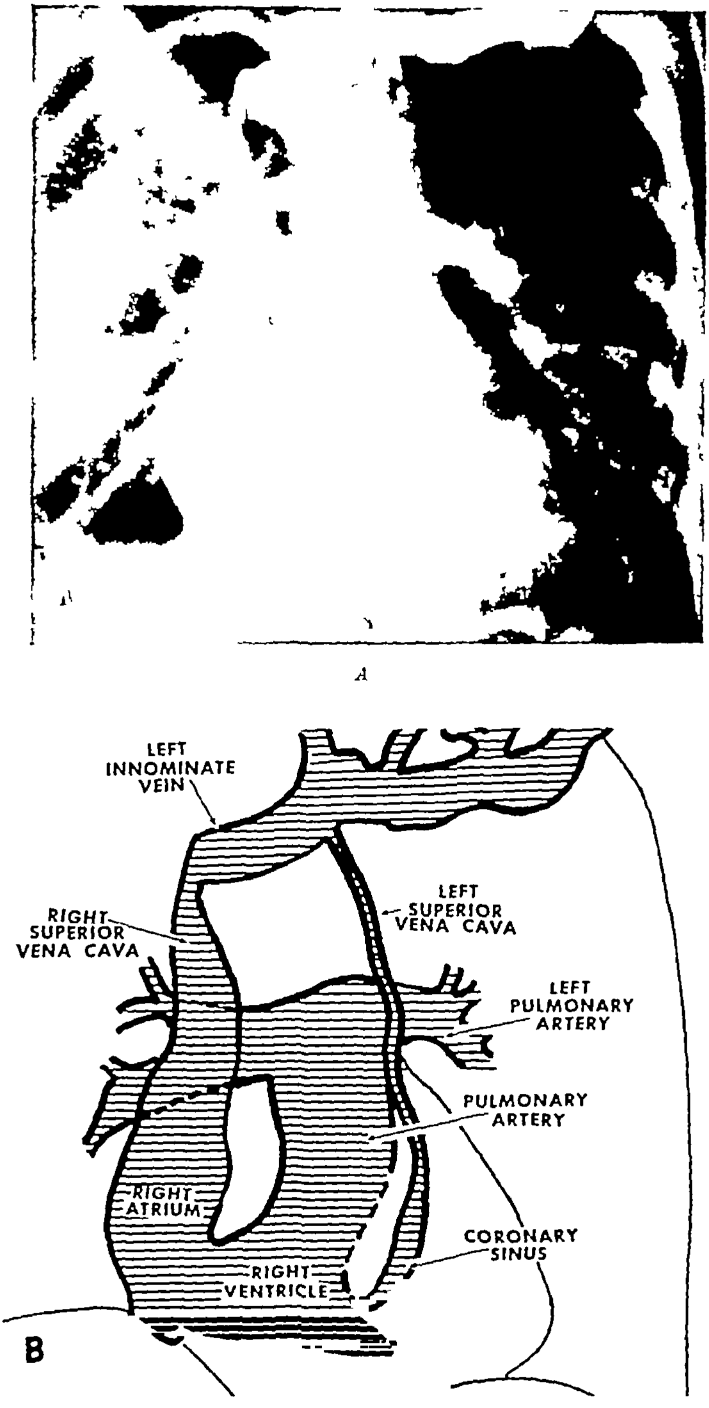
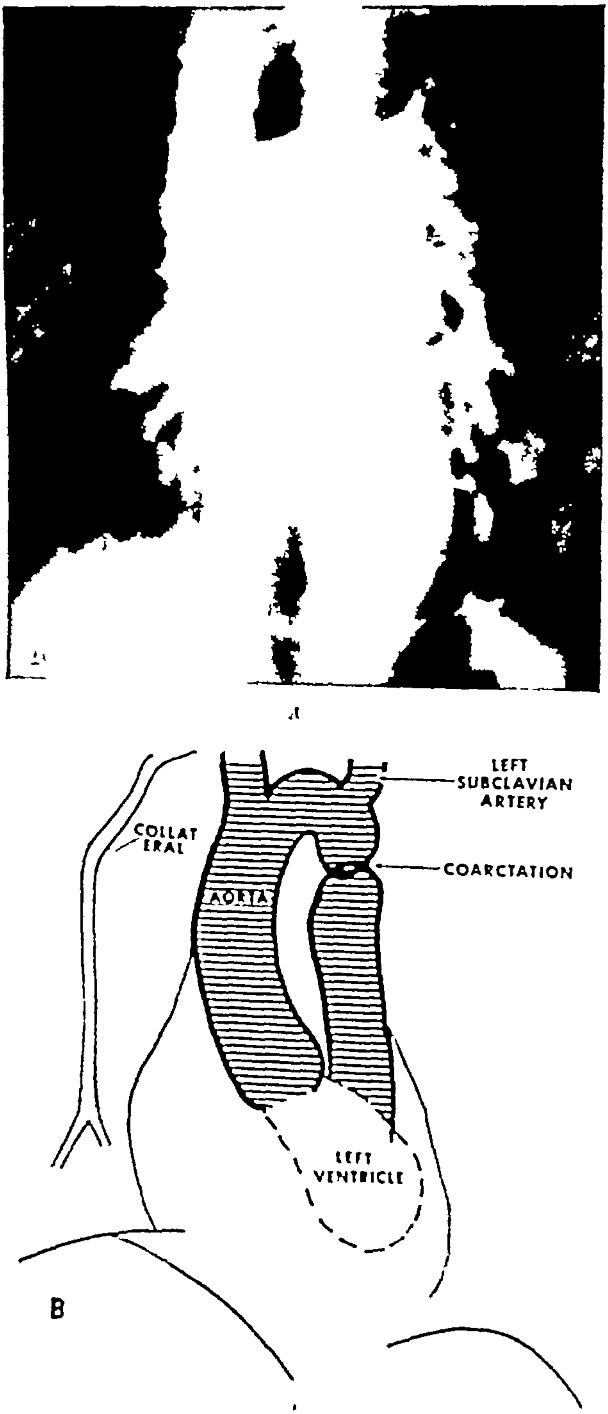


A

B

Fig. 1.—Frontal angiocardiogram. A, Bilateral superior venae cavae, right heart, pulmonary artery, and branches opacified. The rudimentary left superior vena cava empties into the coronary sinus and right ventricle. B, Tracing.


A
LEFT SUBCLAVIAN ARTERY
COLLAT ERAL
COARCTATION
AORTA
LEFT VENTRICLE
B

subclavian arteries. Resection of the coarctation and end-to-end anastomosis of the aorta were easily accomplished. The distal aortic and left subclavian clamps were then cautiously released without any change in the blood pressure. Gradual release of the proximal aortic clamp and a 1,000 c.c. blood transfusion over a twenty-five minute period did not alter the blood pressure which remained between 135 to 140 systolic.

The postoperative course was uneventful and the patient was discharged home on the sixteenth postoperative day. Following operation the blood pressures varied between 170/70 and 148/90; the leg vessels became pulsatile with blood pressures of 140/105 in the right leg and 125/100 in the left. The harsh precordial systolic murmur became soft in quality and the supraclavicular pulsations disappeared.

EMBRYOLOGY OF PERSISTENT LEFT SUPERIOR VENA CAVA

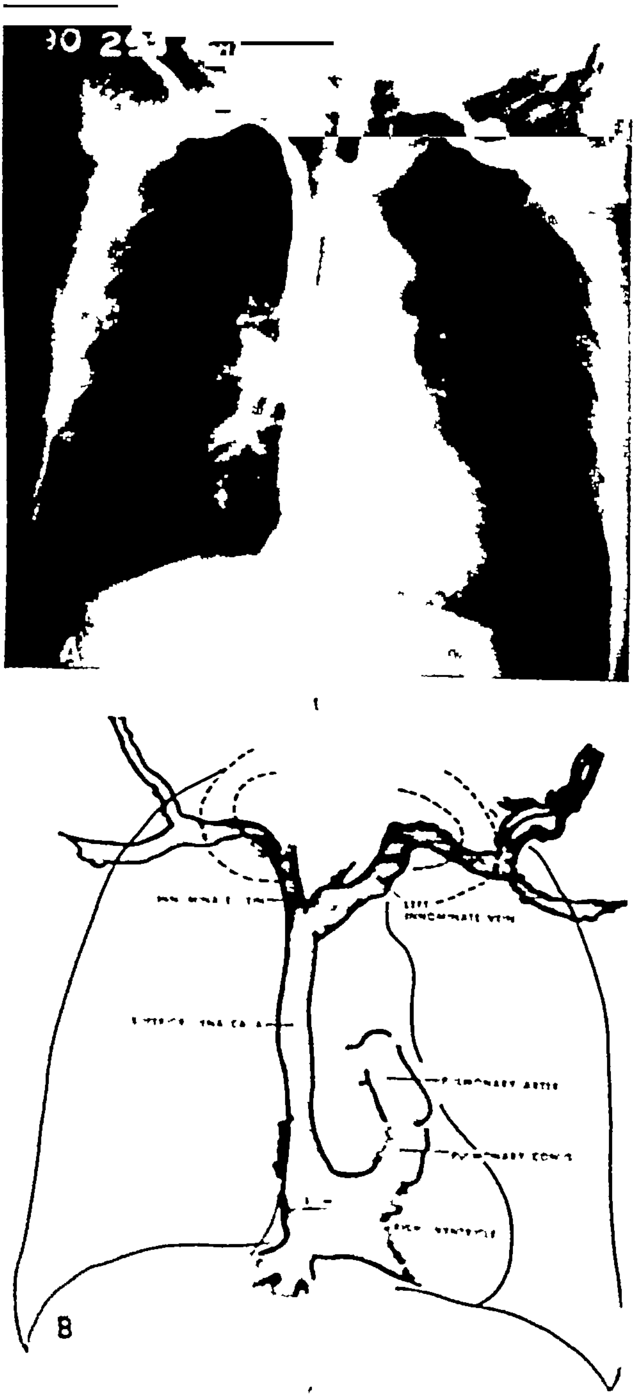
In early development the cephalic portion of the embryo is drained by bilateral symmetrical right and left anterior cardinal veins. These join the posterior cardinal veins near the heart and form the right and left ducts of Cuvier which enter the sinus venosus. During the eighth week of fetal life an oblique communication forms between the anterior cardinal veins and shunts blood from the left vein to the right. This vessel becomes the left innominate vein. The development of the left innominate vein is followed by atrophy of the left anterior cardinal vein. It normally persists as the first left intercostal vein. The left duct of Cuvier persists as the oblique vein of the left atrium *which enters the coronary sinus. This last structure is derived from the left* half of the sinus venosus. The right duct of Cuvier normally becomes the superior vena cava. The fully developed brachiocephalic veins forming the superior vena caval system in the adult are demonstrated in Fig. 3.

If the left innominate vein fails to develop, the left anterior cardinal vein persists and continues to drain the left brachiocephalic veins. In this situation it becomes the left superior vena cava. Since the left duct of Cuvier empties into the left half of the sinus venosus which ultimately becomes the coronary sinus, a persistent left superior vena cava drains into this structure.[1, 4] In our case (Fig. 1) the left superior vena cava persisted in rudimentary fashion while the left innominate vein developed normally.

INCIDENCE AND CLASSIFICATION OF PERSISTENT LEFT SUPERIOR VENA CAVA

Sanders[2] in 1946 on review of the anatomic literature recorded 215 cases of persistence of the left superior vena cava and estimated the incidence to be 1:348 cadavers. Since then many cases recognized by angiocardiography and cardiac catheterization have been reported.[1] The association of persistence of the left superior vena cava and aortic coarctation has been noted four times at autopsy and in one instance only the left superior vena cava without a corresponding right superior vena cava was found.[2] Our case is the fifth instance of the association of the two anomalies and the first to be recognized during life.

In a recent report persistence of the left superior vena cava was classified according to whether associated congenital cardiac anomalies were present or absent. Usually multiple cardiac anomalies were present producing cyanotic types of congenital heart disease.[1] This case is also unusual in that the combined lesions produced a noncyanotic type of congenital heart disease. All but


A
B
LEFT INNOMINATE VEIN
PULMONARY ARTERY
PULMONARY VEINS
LEFT VENTRICLE

one of the previously reported cases had bilateral superior venae cavae. Rudimentary intercommunicating innominate veins were often seen, while a rudimentary left superior vena cava as in this case (Fig. 1) where most of the blood from the left brachiocephalic veins pass through the left innominate vein and into the right superior vena cava was encountered only once previously.[1]

COMMENT

Surgical correction of the aortic coarctation was not hampered by the presence of the persistent left superior vena cava. Contrary to the warning of Brown[8] who thought the anomalous superior vena cava might complicate the operation, no difficulty in repair of the coarctation was encountered. Furthermore, in still another case, a large full-sized persistent left superior vena cava did not interfere with mitral valvulotomy for mitral stenosis.[1] Whereas, the embryological development of a persistent left superior vena cava is easy to understand, the theories of development of coarctation of the aorta are controversial.[9, 10] A direct relationship between the development of persistence of the left superior vena cava and coarctation of the aorta seems unlikely.

SUMMARY

The first case of persistence of the left superior vena cava and aortic coarctation recognized by angiocardiography during life is reported. The persistent left superior vena cava did not interfere with surgical correction of the coarctation of the aorta.

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THE USE OF FIBERGLAS IN PULMONARY TUBERCULOSIS

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THE past two decades have seen a gradual and progressive improvement in the treatment of pulmonary tuberculosis, particularly in the fields of chemotherapy and surgery. This advancement may be attributed to a number of factors, including improved anesthesia, improved knowledge of cardiopulmonary physiology, improved surgical techniques, chemotherapy, and [illegible] in pre- and postoperative care.

Despite this improvement and advancement there still remain many patients in whom the prognosis remains poor and for whom the outcome is [illegible] some other approach than the orthodox one cannot be de[illegible]. Attempts to solve this problem have taken on numerous aspects; however, the underlying principle has remained essentially the same, namely, [illegible] extrapleural or extrafascial pneumonolysis. This method of [illegible] has provided certain advantages not inherent in other presently [illegible] types of surgical approach, including pneumothorax, pneumoperitoneum, thoracoplasty, lobectomy, and pneumonectomy. These advantages [illegible]

In June, 1948, O'Neil and his associates presented their experimental findings in animals and human beings wherein Fiberglas wool and Fiberglas fabric were used. Their demonstration showed that a very minimum of tissue reaction occurred around the implanted Fiberglas mass when their recommended technique was followed. It therefore appeared from their studies that this substance presented a material sufficiently inert to merit serious consideration and an adequate period of trial in human patients.

The use of Fiberglas wool and Fiberglas fabric was undertaken at this Clinic in September, 1948, and since that time fifty-four patients have undergone this procedure.

In the early stages of the study the classical technique for extrapleural pneumonolysis was followed and the technique for applying the Fiberglas followed that described by O'Neil and his associates.

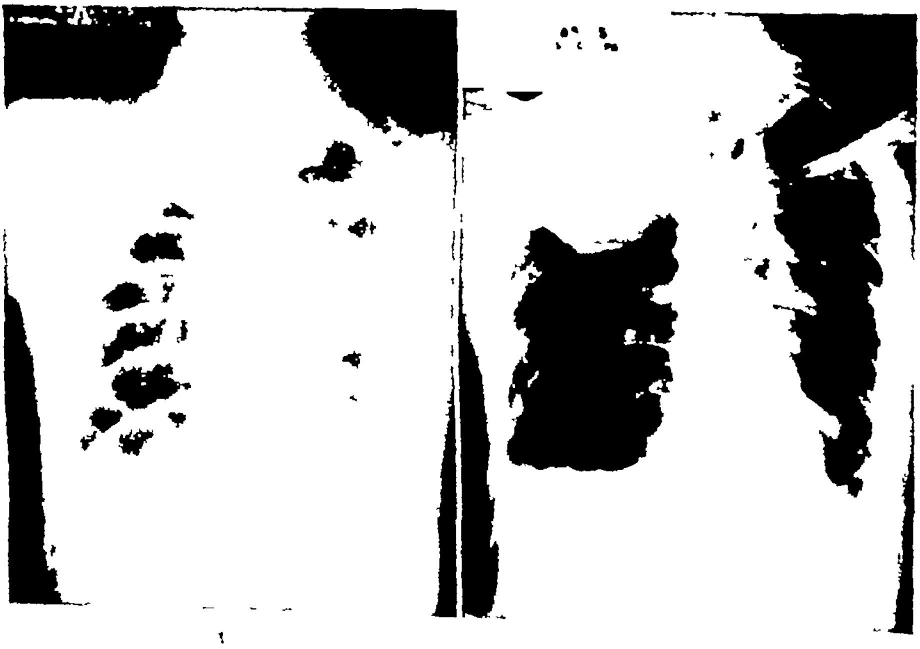
Among this group of patients, three developed infections in the plumbage space. One case of infection definitely followed cavity wall necrosis in an otherwise desperately ill patient. This resulted fatally. The remaining two cases could not be explained on any apparent basis. It was therefore concluded that the source of infection could well have come as a result of the interruption of the continuity of the mediastinal lymphatics, thereby opening avenues of infection into the surgical area.

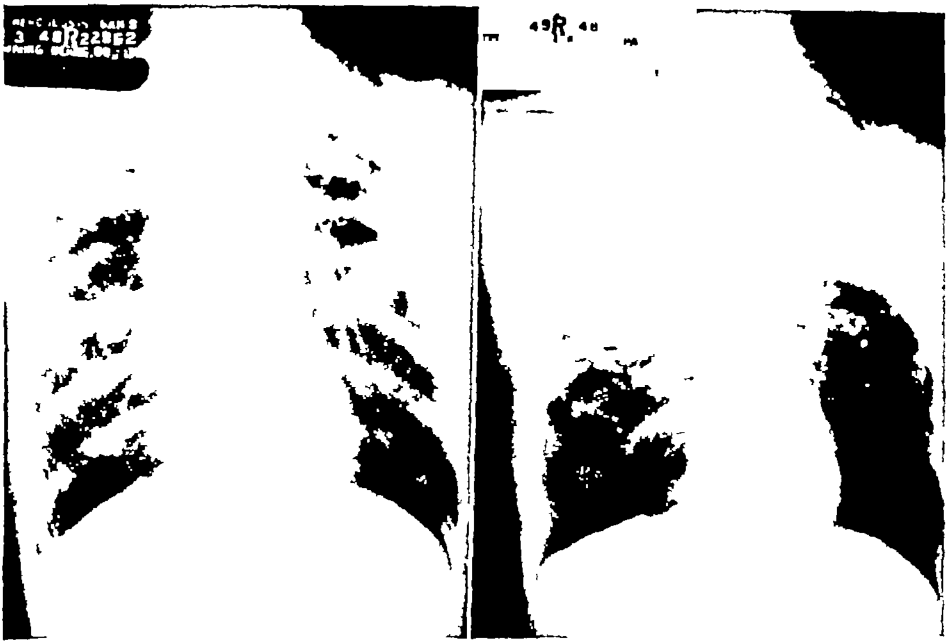
In consequence of this conclusion, the extrapleural technique for creating the collapse was abandoned and the extraperiosteal (extrafascial) technique adopted. Following the adoption of the changed technique, one infection occurred. It was in a patient (age 38) who had recently undergone a radical mastectomy for carcinoma of the breast on the ipsolateral side. This occurrence therefore was not considered a contraindication to further use of the procedure.

It was felt that the extraperiosteal technique constituted an improvement and afforded the patient a reduced possibility of a complicating infection. There remained one possible difficulty, and this required the passing of considerable time to evaluate fully the fate of the ribs following the removal of their periosteum. It was expected that they might undergo at least some degree of osteoporosis. This did occur and was therefore considered to constitute a decided disadvantage. Subsequently, using parallel incisions along the upper and lower margins of the ribs, the external periosteum was left in place.

We are not unmindful of the fact that the extraperiosteal technique has been employed heretofore under different circumstances (extraperiosteal pneumothorax) and has been quite thoroughly condemned. However, it is felt that the procedure has certain inherent advantages if the disadvantages can be overcome. If Fiberglas is inert, and indications at that time attested to the fact that it is, then a plumbage using that material would not create a dense fibrous capsule, its removal would be accomplished with ease, and the operative field would be available for some other procedure in the event the plumbage proved ineffectual. Such has been our experience to date.

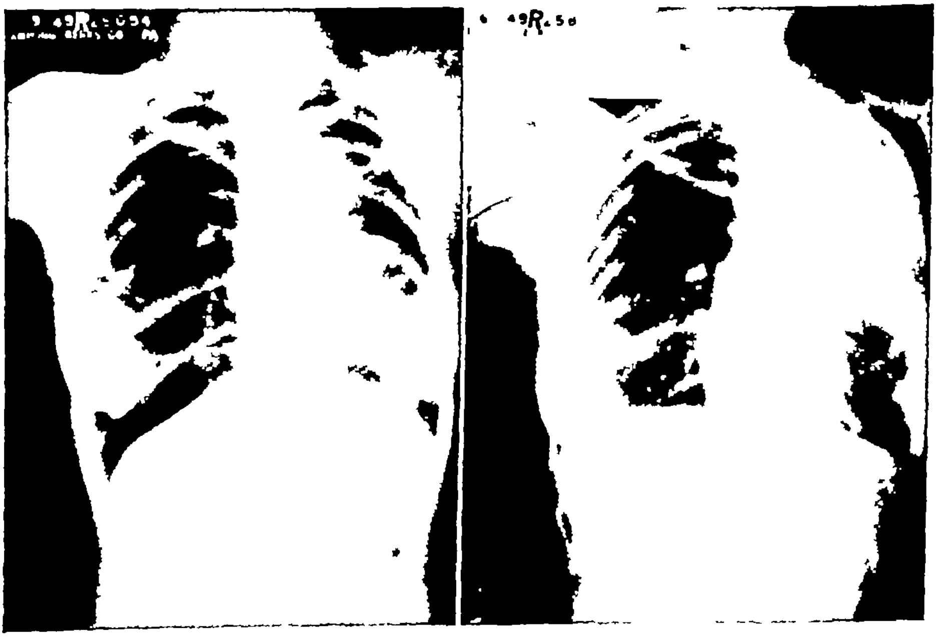
The advantages lie chiefly in the fact that the mediastinal lymphatics and the possible peripheral blood supply to underlying cavity walls are not disrupted, complete decollation of the apex need not be effected, and therefore the tendency of the apex to drop downward, as in an extrapleural pneumonolysis, does not become a factor. The management of the freed periosteum constituted a major consideration at the outset. At first the periosteum was formalinized to preclude bone regeneration, but later it was discovered that this precaution could be abandoned with impunity. Resection of the partially denuded ribs at a subsequent operation can be performed with a minimum of trauma and with the loss of an absolute minimum of operative time. Thus, should regenerated bone develop and its removal become necessary, this may be accomplished with no greater trauma and in much less time than a revision (secondary) thoracoplasty.





A B

Fig. 2.—W. Z. A successful bilateral Fiberglas plumbage collapse in a patient in whom a bilateral thoracoplasty of a satisfactory extent could not have been performed safely.



A B

Fig. 3.—F. T. A successful plumbage collapse in a 14-year-old child in whom a posterior thoracoplasty of seventh to eighth ribs, scoliosis would otherwise present a serious problem.

A
B

A. *Extrafascial.*—

1. Patients with bilateral disease where a thoracoplasty has been or is planned for one side, bilateral thoracoplasty being considered undesirable because of the late discomfort to the patient or bilateral thoracoplasty being considered likely to result in respiratory insufficiency (Fig. 2.)
2. Patients in whom a multiple stage thoracoplasty is contraindicated because of a serious nonpulmonary complication such as cardiac disease.
3. Patients who because of advanced age are not considered good surgical risks for a multiple stage operation. This frequently but not always includes patients over 60 years of age.
4. Young patients who without *prolonged good orthopedic care might* develop *a consequent* severe *scoliosis if a multiple stage thoraco*plasty were to be performed. This *group generally includes in*dividuals below *the age of 20 years* (*Fig. 3.*)
5. Patients who refuse the indicated type of operation generally thoracoplasty because of fear, cosmetic reasons, etc. and who may be salvaged and very possibly returned to society (Fig. 4.)

B. *Extrapleural.*—

At the outset eleven patients (one bilateral case) were operated on *according to the standard extrapleural technique. Nine cases were entirely successful and three patients developed infections in the extrapleural space. Prior to the development of these infections, the same criteria as were just* described for the extrafascial operation were considered to comprise the indications for this procedure. However, following the perforation of the cavity in the one case and the occurrence of infections in the two others it was felt that patients having cavities over 2 to 3 cm. in diameter probably should not be subjected to this type of technique and if so only if the complete x-ray history could be obtained and convincing evidence obtained that the cavity in question had never been larger than that shown on the preoperative roentgen films.

MATERIAL

The *Fiberglas* fabric, which is known as "116 cloth,"* is 0.004 inch thick and is of balanced Fiberglas 450 1/2 yards, 60 ends per inch in the warp and 58 per inch in the fill. Each strand is formed of approximately 200 individual filaments. The average filament diameter is approximately 0.00022 inch. The Fiberglas wool is the Fiberglas superfine wool composed *of* glass fibers randomly oriented in a batt. *All filaments* in both the batt and fabric are resin free and uncoated. *Both batt and fabric are prepared preoperatively* by boiling *for forty minutes on four consecutive days and are delivered warm to the operating table. Should the quantity of the material delivered to the operating table be* in excess of the *amount required the remainder may be spread thinly on a clean towel,* dried and reprocessed in like manner when subsequently needed.

TECHNIQUE

The procedure adopted in the extrapleural group *follows* the standard technique. With the patient lying in the lateral position, a curved periscapular incision is mad

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*Supplied through the courtesy of the Owens-Corning Fiberglas Corporation.

formance of the necessary obliterative thoracoplasty. This death was attributed directly to an unrecognized massive pericardial effusion discovered at autopsy. Of the remaining forty patients, thirty-four (62.96 per cent) became sputum negative or have had an apparently satisfactory collapse on the plumbage side. There are, however, three patients in whom the sputum is still positive, but as a result of tuberculous lesions in the contralateral lung or in areas of the same lung at a distance from the region under the plumbage. All these lesions have developed many months after an apparently successful plumbage collapse; two of these patients have subsequently undergone a successful total pulmonary resection, and in two it has been possible to collapse the cavity by an additional Fiberglas implantation (Fig. 4). One of the two remaining positive patients may in time be subjected to a pulmonary resection because of a basal cavity which has developed after the original plumbage was instituted.

TABLE II. ANALYSIS OF INFECTIONS AND TREATMENT

Total patients infected	13
Total plumbages infected	14 (1 bilateral)
Necrosis of cavity wall	1
Shortest period postoperative before infection	59.0 days
Next shortest period postoperative before infection	102.0 days
Longest period postoperative before infection	1,121.0 days
Average period postoperative before infection	403.0 days
Removal of plumbage and thoracoplasty and simple drainage	8
Removal of plumbage and pneumonectomy and thoracoplasty	2
Removal of plumbage and thoracoplasty with negative pressure suction	2
Decortication of middle and lower lobe and thoracoplasty (3 ribs)	1

COMPLICATIONS

For the purpose of comparison it is well to consider the extrapleural pneumonolysis (plumbage) and the extrafascial cases separately. During the early stages our patients experienced a marked sensation of pressure within the plumbage area. This was found to be due to the fact that the Fiberglas wool will absorb a quantity of fluid and expand, especially if the wool pledgets are not sufficiently moist when placed within the Fiberglas fabric bag. This difficulty was overcome by placing a small (14 to 16 F.) fenestrated catheter drain in each created space for twenty-four to forty-eight hours. (No infections resulted from this practice.)

One patient experienced a small hemoptysis and some streaking of the sputum two weeks postoperatively. Although the bleeding was attributed at the time to the plumbage, the development of an additional tuberculous cavity within four months in another portion of the lung (subapex of lower right lobe) suggests the possibility of a different source of the bleeding other than the effect of the plumbage. Three patients developed infections in the extrapleural space, one because of perforation of the cavity (Fig. 5). In this case the Fiberglas was removed, the ribs were resected, and the area was drained. The patient was profoundly ill before the original operation. The added toxemia of the mixed infection and the insult of a second operation proved to be too great a burden upon the physiologic system, and the patient died. Two additional individuals developed a pure tuberculous infection in the extra pleural space. This was attributed to the possible fact that the lymphatics had been disrupted in the mediastinal area, thus opening possible channels of infection so that tubercle bacilli gained entrance into an area not yet

thoroughly sealed off where conditions were optimum for the culture and growth of the organisms. No other complications have developed directly as a result of this type of technique. However it was felt that the hazards of such infections warranted virtual abandonment of the extrapleural procedure as such and the development of an alternate.

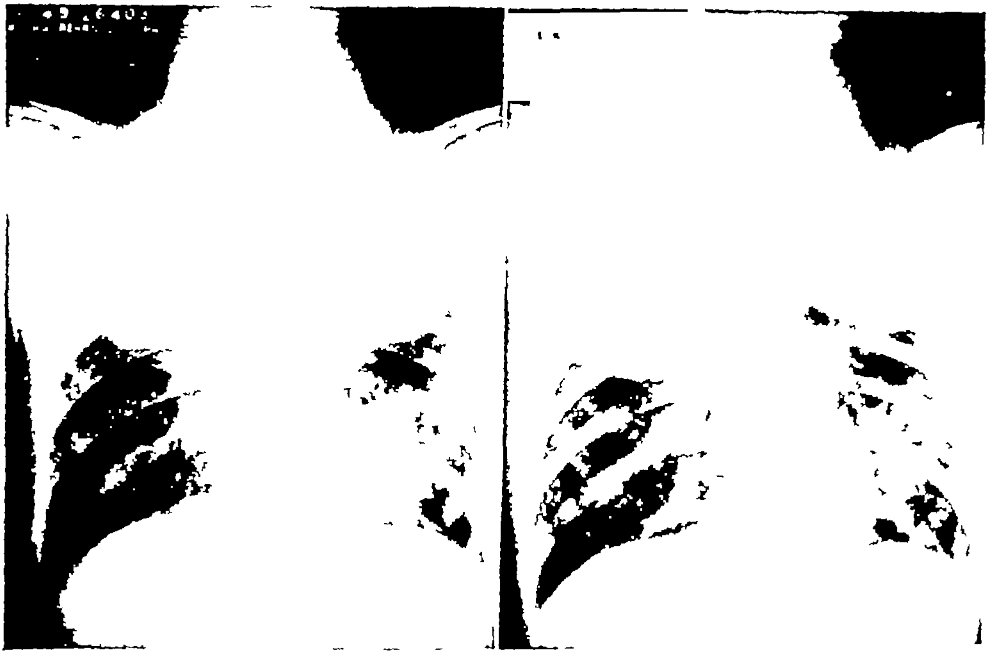
A B

Fig. 6.—T. I. *A*, Apparently successful bilateral collapse. *B*, Note increase in area of collapse on right side. This indicates increase in "fluid content" of the fiber mass in this instance pu

The extrafascial approach was therefore adopted and was used up to the time the Fiberglas plumbage was abandoned.

One instance of a pyogenic infection occurred in a patient who fifteen (119 days) weeks previously had undergone a radical mastectomy for carcinoma of the breast. In retrospect it is felt that either the operation should have been postponed or some other procedure should have been substituted. Likewise speculation suggests that patients in whom the soft tissues of the chest wall are scanty as in the patient who is actually emaciated, performance of a Fiberglas plumbage or extrapleural pneumothorax etc. should be undertaken with the utmost caution since a "stitch abscess" or an otherwise minor infection may well discharge infected material or organisms inwardly as well as outwardly, thus leaving the plumbage a likely site for gross infection.

Two additional patients in this group showed manifestations of profound respiratory insufficiency and it was necessary to remove the plumbage in both instances. Following the removal of the Fiberglas both patients showed rapid improvement which continued without further need for oxygen. Preoperative studies had indicated that we were justified in proceeding with these individuals but with caution. These studies however did not suggest that either patient should have been as seriously hypoxic postoperatively as occurred even in view of recognized limitation of diaphragmatic motion in one. The prognosis in both of these cases was thereafter considered grave and the patients eventually died.

In addition to these three cases of extrafascial plumbage and the two of the extrapleural group there has been a total of thirteen (fourteen plumbages) patients who developed an infection in the plumbage area up to this time. We fear that there is a strong probability that still others will at some time follow the same discouraging pattern (Fig. 6).

DISCUSSION

It is no longer too early to evaluate this type of prosthesis. After a four-year follow-up with findings at autopsy or on subsequent operation it appears that Fiberglas is extremely nonreactive as originally claimed. It seems to be a reasonable assumption that very possibly in this lack of reaction resides the principal disadvantages of this type of prosthesis. The degree of reaction around the prosthetic mass is indeed minimal. The patient after recovery is completely comfortable and quite unmindful of its presence. So far there has been no difficulty encountered in removing the prosthetic mass irrespective of the length of time it has remained in the individual patient. In certain cases it was initially believed that the Fiberglas could be removed and the lung re-expanded provided that such had been anticipated and the periosteum had been well formalinized at the time of the original operation. Later experience has necessitated a complete change of this optimistic view. In our cases little or no bone re-formation occurred while the Fiberglas was in place but when it was finally removed and the overlying ribs were resected [illegible] bone has developed. Finally there appears to be but limited [illegible] or absorption of the partially denuded ribs except in the presence [illegible] current infection. Infection, we feel, prevents the establishment of [illegible] blood supply from the soft tissues of the chest wall following the adher[illegible] to the bony substance. Perhaps the blood supply from the [illegible] periosteum becomes inadequate to meet the emergency demands [illegible] upon it by an infection. The advantages of Fiberglas over other [illegible] initially appeared striking and obvious [illegible] been nullified by the apparent susceptibility of these [illegible] to infection. Paraffin has advantages over all the other [illegible] ever having employed both materials it is our [illegible] in all respects except [illegible]

TABLE III. SUMMARY TABLE C

Total cases		54
Total bilateral plumbages		6
Total patients infected	13	14
Total bilateral patients infected	1	
Total new tuberculous cavities developing		2
Total patients dead, all causes		14
Total positive sputum		
a. Source unknown		1
b. Contralateral tuberculosis		
c. New cavities, same side		5
(2 pneumonectomized successfully)		
additional plumbages (same side)		2
d. Total remaining positive sputum		2
Gross total—successful plumbages (per se)		[illegible]
Net total—successful plumbages		4

of the Fiberglas to incite a tissue reaction precludes the production of a fibrous tissue that would otherwise infiltrate the Fiberglas mass, hence the mass takes up a quantity of tissue fluids that in turn provide a good culture medium for tubercle bacilli and or other organisms at some future time. The Fiberglas plumbages that have been removed for reasons other than infection have all been quite moist and contain a generous supply of a clear straw colored fluid (bacteriologically sterile). Futhermore the underlying lung was freely movable with each respiratory cycle and the surrounding capsule was exceedingly sparse or nonexistent (maximum depth of reaction 1 to 2 mm.). Re-formed bone in the extraperiosteal group of cases was generally absent even though *no formalinization of the periosteum or removal of the intercostal structures* was practiced at the time of the original operation.

SUMMARY

1. Fifty-four cases in which a Fiberglas plumbage has been performed are reported.

2. Fifteen (27.77 per cent) patients are dead from all causes.

3. Fourteen (26 per cent) have developed pyogenic, tuberculous or mixed infections in the plumbage area.

4. Two patients have subsequently undergone pulmonary resection because of definite tuberculous cavities and another is expected to become a candidate for a similar procedure.

5. Thirty-four (62.96 per cent) have remained satisfactory after a four-year follow-up, the last case having been performed thirteen months ago.

6. This procedure is being reported to show the hazards and not to recommend its adoption as an acceptable method of collapse therapy.

Acknowledgment.—We wish to express our sincere thanks to the Owens-Corning Fiberglas Corporation for supplying the materials used in this study and likewise to Mr. Morris, their representative, for his assistance and his many courtesies extended to us.

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TRANSVERSOAXIAL TOMOGRAPHY AS A VALUABLE HELP IN ESTIMATION OF OPERABILITY OF PULMONARY CANCER

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THE determination of operability of lung cancer by means of the methods discussed in current available investigations is often very difficult. The degree of invasion and of fixation to the pericardium and to the pulmonary veins remains generally a complex problem which the radiologist tries to solve for the surgeon.

Yet, besides bronchoscopy, radiography is the essential means of diagnosis and investigation in lung cancer. The current anteroposterior and lateral films with their cross view of the tumor give us basic information. Frontal tomography helps us to clarify some interesting points: size, shape, involvement of a main or even secondary bronchus, and spreading bronchogenic lesions. Lateral tomography gives a better localization of the tumor. But none of the routine tomograms provides reliable information about the extension of the tumor to the mediastinum. Finally, angiopneumography proposed by Neuhoff and [illegible], Santy, Sauvage, and Weiss, and discussed by Olivier Monod, gives, besides interesting anatomic precisions, indirect indications based upon the arterial images of the degree of operability. However, this method is neither always adequate nor free from risks.

Therefore, if we evaluate the present radiologic possibilities, we come to the conclusion that the simple films and tomograms enable us to diagnose and to localize the tumor, to determine its size, its bronchial and to a certain extent its [illegible] involvement. We agree also that angiocardiography can localize the tumor within the pulmonary arterial system and sometimes demonstrate exactly [illegible] operability. But there is as yet no solution to the problem of the extension [illegible] and pulmonary veins. It is therefore very difficult and [illegible] to tell the surgeon whether or not he will find the mediastinum [illegible] and whether or not the invasion of the peri[illegible] the mediastinal organs will be brought out clearly enough so that it will be possible to determine whether a plane of cleavage exists or whether there is extension to the mediastinal organs. Thus whereas anteroposterior and lateral

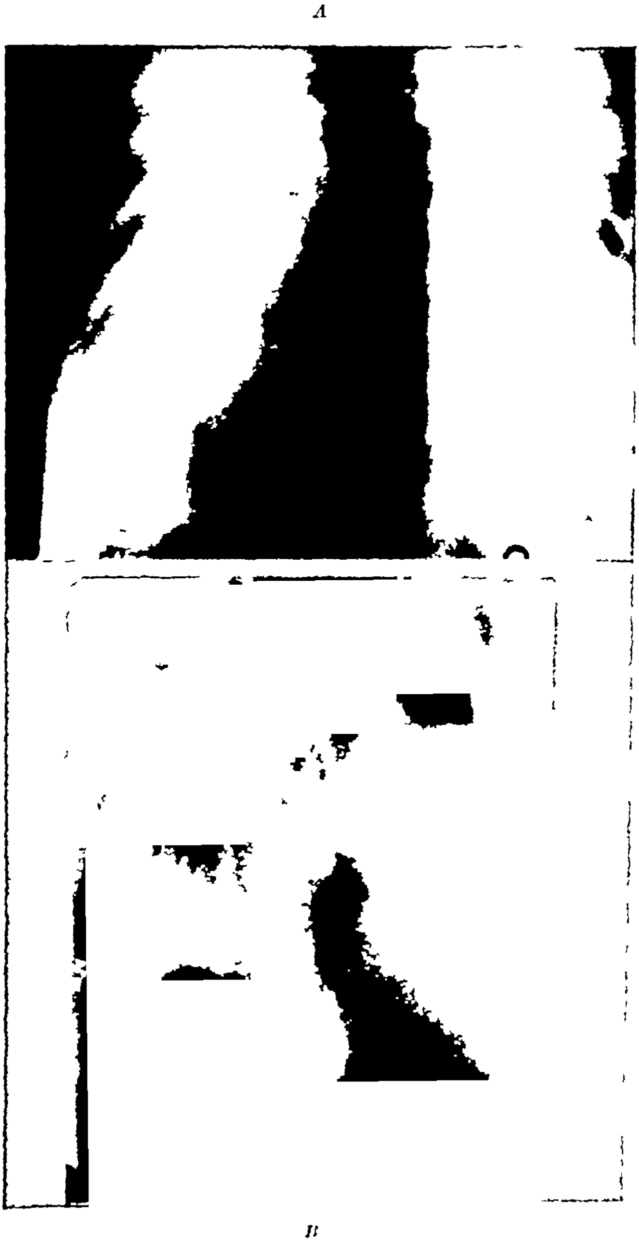


Fig. 1, A and B. (For legend see opposite page.)

tomograms fail to give us accurate precision as to the degree of operability of a bronchopulmonary tumor, horizontal tomograms provide us with most important additional information.

Having this in mind, we have used this method of study for over one year in all cases of pulmonary cancer we have had the opportunity to see and whose operability seemed questionable on routine tomograms. These patients were thoroughly studied radiologically and the operative findings carefully correlated.

Of our series we shall present only three cases, ranging from an easily removable small tumor to a complicated and inoperable one.

Case 1.—Mr. E. B. On the frontal tomogram (Fig. 1, A) a rounded, orange-sized [illegible] appears in the right hemithorax. Its inferior outline fades into the cardiophrenic angle. The lateral tomogram (Fig. 1, B) shows a rounded mass located within the right posterior paravertebral gutter. The limits of the tumor are confused with the posterior wall of the thorax.

The transverse axial tomogram (Fig. 1, C) shows a mass located within the costovertebral [illegible] posteriorly. A very distinct line of cleavage appears which separates it from the right side of the spine. The mediastinum is free.

According to the transverse axial tomogram, the resection is certainly possible. This was [illegible]

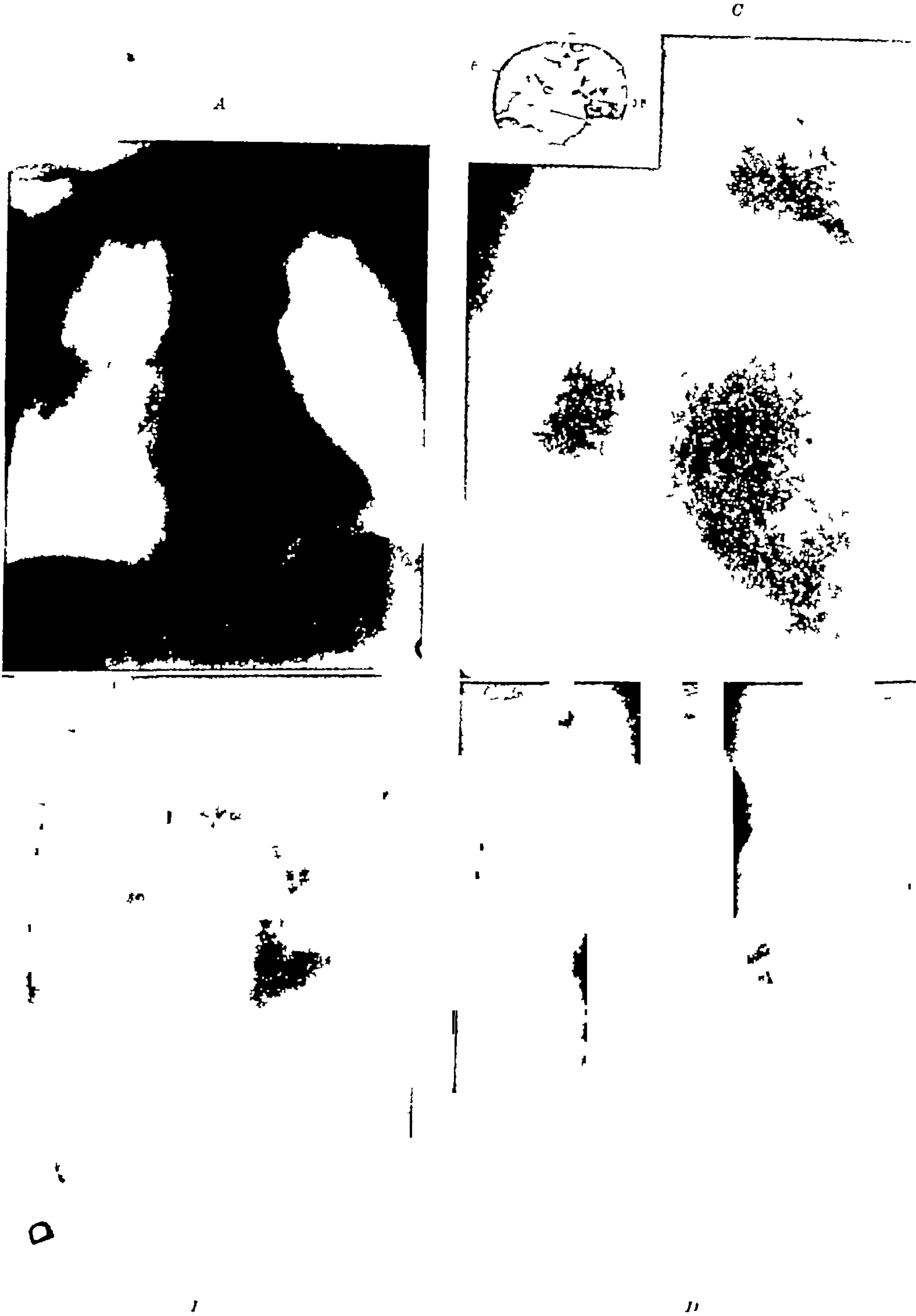
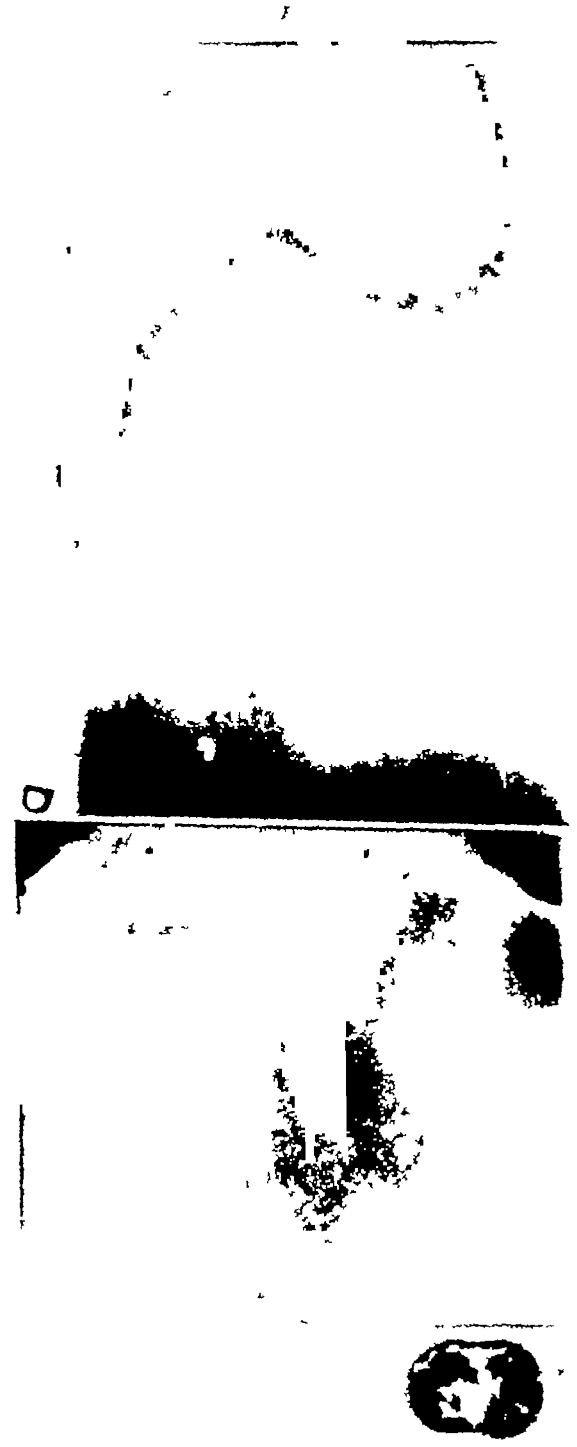


FIG. [illegible].—C[illegible] [illegible]. A, Frontal tomogram. B, Lateral tomogram. C, Transverse axial tomogram. 1, Aorta; 2, left pulmonary artery; 3, left main bronchus and left upper lobe bronchus; 4, heart and main vessels and tumor confused.

After radiotherapy: D, Frontal tomogram. E, Lateral tomogram. F, Horizontal tomogram. 1, Ribs; 2, aorta; 3, main right and left bronchi; 4, left pulmonary artery; 5, heart; 6, tumor; 7, main scar.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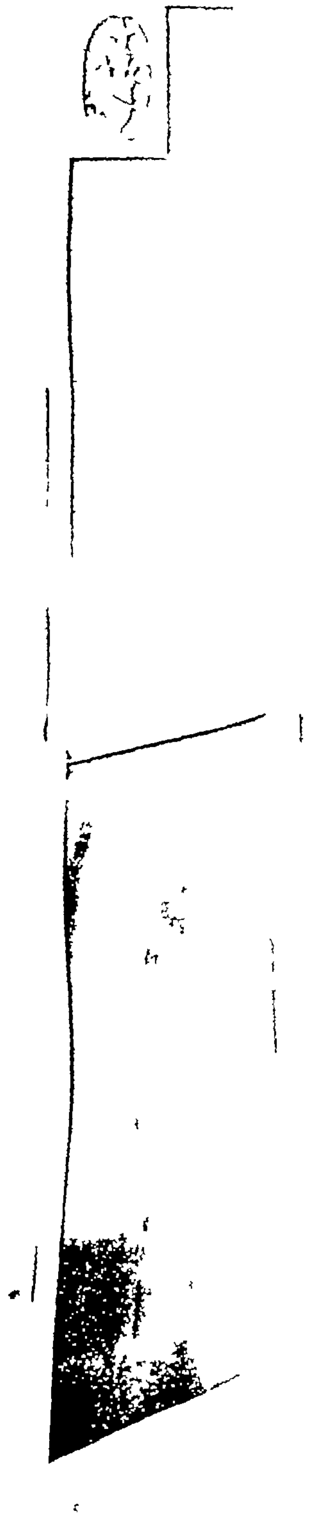

Transversoaxial tomogram (Fig. 2, C) shows a big tumor mass within the right hemithorax. The outline is faintly visible; the tumor mass and the heart form one block in which no cleavage plane appears. The obvious conclusion is that the tumor is inoperable.

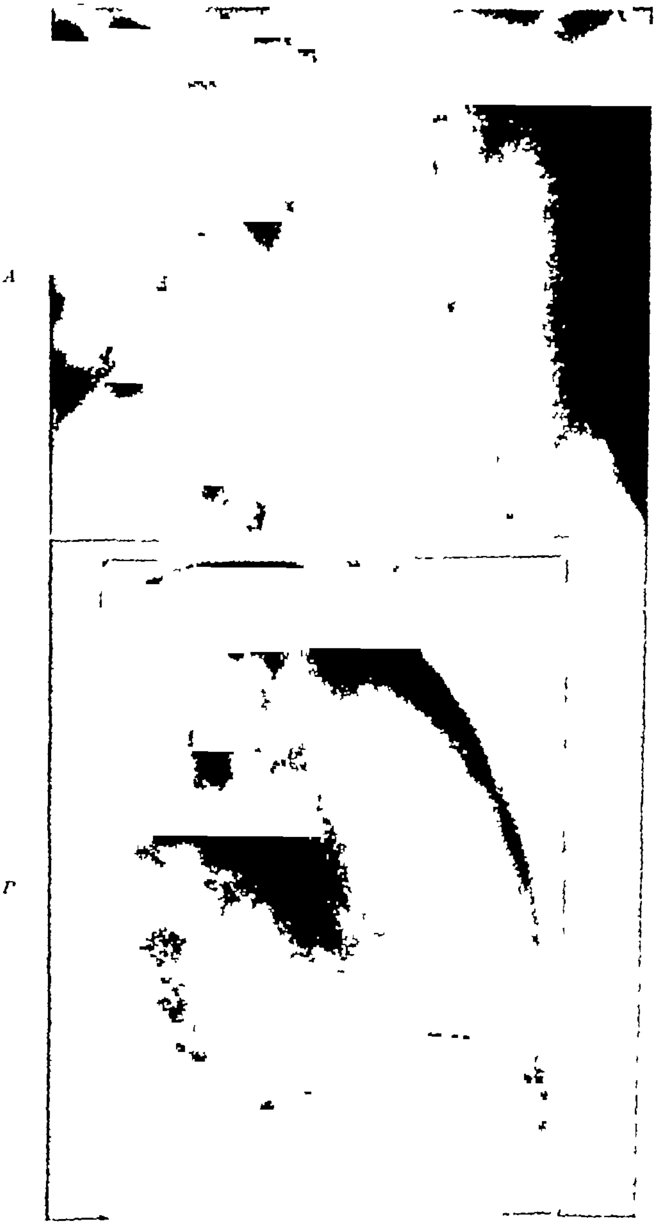

Fig. 2.—Case 3. A, Frontal tomogram. B, Right lateral tomogram. C, Horizontal tomogram. 1, Aorta; 2, left main bronchus; 3, the right main bronchus is compressed; 4, heart; 5, tumor.

Inoperability was confirmed by thoracotomy.

After radiotherapy, new x-ray films show these findings. On the frontal tomogram (Fig. 2, D) there is an irregular tumor mass between the upper and middle lobe bronchi.

The lateral tomogram (Fig. 2, E) supplies little information. We see a small parahilar mass whose extension cannot be determined.

In [illegible] (Fig. [illegible] F) [illegible] mass of the tumor on the right side [illegible] between the tumor and the heart. This distinct space [illegible] the possibility of operation.

The [illegible] medical [illegible] with mediastinal lymph [illegible]

Case [illegible]—Mr. T. K. The frontal tomogram (Fig. [illegible]) shows the presence of a big [illegible] It occupies the lower part of the right upper lobe and [illegible] to 10 [illegible]

The right lateral tomogram (Fig. [illegible]) shows the tumor centered on the hilum, partial [illegible] and invasion of the middle lobe.

On [illegible] (Fig. [illegible] C) we see a big tumor mass whose mediastinal [illegible] The right [illegible] bronchus strangled by the tumor [illegible] behind it appears [illegible] The mass obviously [illegible] A [illegible] centre of the inoperability.

[illegible]

Fig. 4

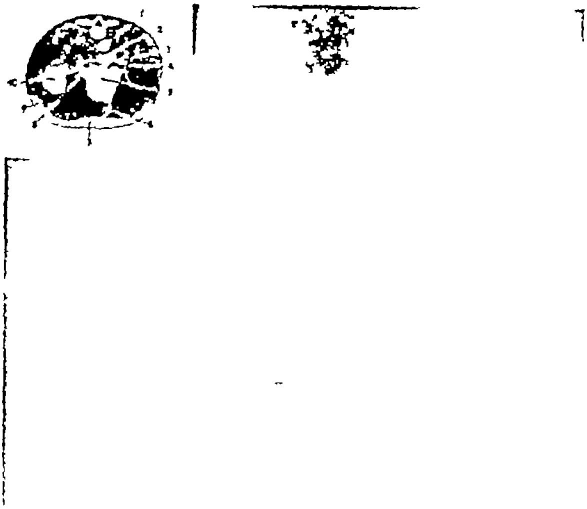

Fig. 5

Fig. 4.—Case 4. 1, Aorta; 2, intermediate bronchus; 3, left pulmonary artery; 4, left main bronchus and upper lobe bronchus; 5, heart; 6, pericardial ligament; 7, anterior chest wall; 8, right pulmonary artery; 9, tumor.

Fig. 5.—Case [illegible]. 1, Right main bronchus; 2, aorta; 3, left main bronchus; 4, left pulmonary artery; 5, heart; 6, tumor; 7, right pulmonary artery.

of the heart are sectioned perpendicularly to their axes and appear clearly outlined. However, the images of the left hemithorax are more difficult to identify.

Figs. 4 and 5 are two horizontal tomograms showing tumors of the right [illegible] which will illustrate this difference when compared to the third [illegible] in Fig. 6 showing a tumor in the left [illegible]

Case 4.—Mr. F. M. T. [illegible] (Fig. 4) shows a rounded orange-sized mass in the right [illegible] from the clearly visible right border of the heart [illegible] main bronchus being cut just [illegible] the tumor is operable

[illegible] M. T. On the film (Fig. 5) the tumor is in very close contact with the [illegible] artery. The main bronchi are well visualized. The right border [illegible] that this is a borderline case for surgery, but [illegible] confirmed this diagnosis.

The patient was operated on and the tumor found resectable This case illustrated the difficulty in reading and interpreting horizontal tomograms in the left hemithorax

We have tried to bring out the superimposed shadows by means of pneumomediastinum By injecting air we hoped to separate and isolate the organs The results have not been satisfactory Some zones of clearing correspond no doubt to anatomic cleavage planes also found during operation but there are others that pneumomediastinum is unable to bring out because the air cannot penetrate them Furthermore edematous congestive connective tissues are also impenetrable to air although they are no obstacle to surgery This slight improvement in radiologic outlines is therefore of no appreciable value, and the contribution of pneumomediastinum no longer significant in the evaluation of operability in pulmonary cancer

In conclusion we believe that transversoaxial tomography will give precise information as to the tumor involvement of the vertical intrathoracic organs only, the transversal section of these being strictly horizontal Information is less accurate where the organs have a development and anatomic disposition not following this rule the ascending aorta the arch of the aorta and the left side of the heart Valuable on the right side transversoaxial tomography will be untrustworthy on the left Its reading is still complex and its interpretation difficult Technical improvement will in the future certainly make those tomograms easier to interpret in giving better outlines of tumors and mediastinal organs

SUMMARY

1 The degree of adhesions of a pulmonary cancer to the mediastinum to the pericardium and to the pulmonary veins is always difficult to determine

2 The frontal and lateral radiograms and tomograms give only fragmentary information

3 Horizontal tomography cutting transversally the intrathoracic organs with vertical axis gives direct knowledge of the degree of fixation of the tumor to these organs It indicates and outlines an eventual plane of cleavage between them and the tumor

4 The importance of the information obtained is at least equal to that given by bronchoscopy about bronchial patency, or to that of the accessible length of pulmonary artery determined by angiopneumography It is information about the relationship of the tumor mass to mediastinum veins and pericardium

5 The value of this information however is not the same on both sides Very reliable on the right where it cuts only vertically disposed organs horizontal tomography does not give very valuable information in the left hemithorax because of the oblique position of the heart and of the aortic arch which appear as one with the tumor

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BENIGN EPICARDIAL CYST

A Case Report

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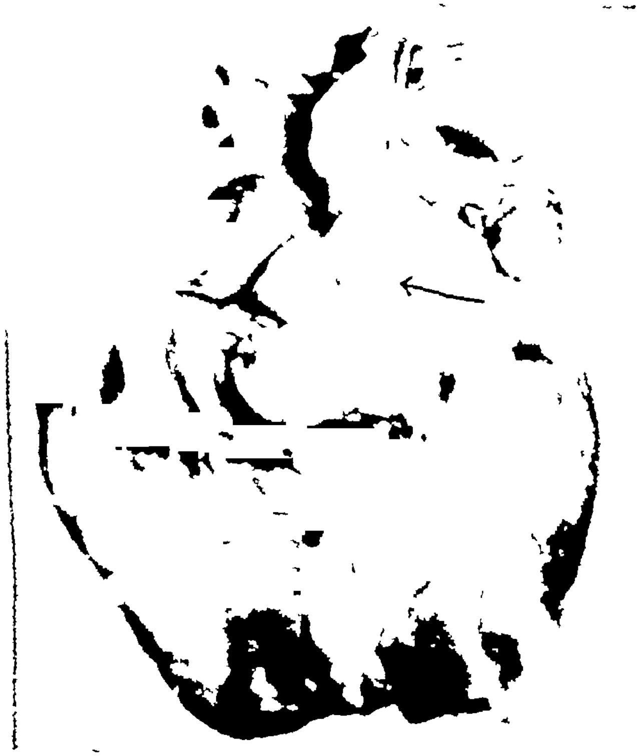
PRIMARY tumors of the heart occur infrequently; survey of the available literature reveals less than two hundred cases reported to date. A slightly larger number of pericardial cysts have been reported; however, most of these pericardial cysts, according to their description, were derived from parietal pericardium. Only one definite reference to a cystic tumor of the epicardium (visceral pericardium) could be found.[1]



epicardium found in the right atrioventricular groove. This was located on the anterior aspect of the heart and at the root of the great vessels (Fig. 1).

It measured 2.5 by 1.4 by 1.4 cm. The wall was smooth, thin, and transparent, and the fluid contained in the cyst was clear, colorless, and watery.

Microscopic examination revealed only a single layer of cells of the mesothelial type lining the cyst supported by a few fibroblasts. Mesothelium of the epicardium was reflected onto the cyst anteriorly, and posteriorly it was separated from the pulmonary artery by a small amount of fibrous tissue (Fig. 2).

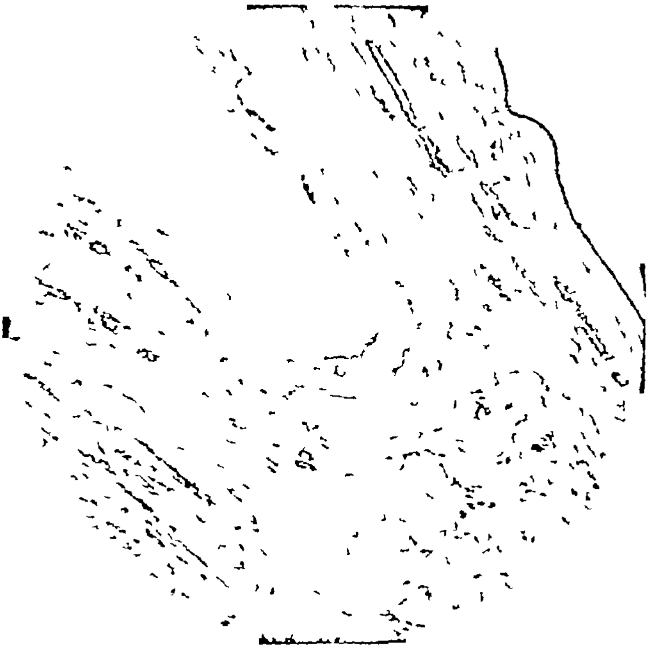


Fig. 2.—Photomicrograph showing mesothelial lining of cyst in right upper corner. On the left the epicardium is reflected over the cyst while elastic fibers of the pulmonary artery are visible in the left lower corner (×20; hematoxylin and eosin stain).

DISCUSSION

As a rule the primary tumors of the heart are clinically silent; only two cases are on record which were diagnosed prior to death. No case of benign tumor has ever been diagnosed before death. About 20 per cent of these tumors are malignant and the younger age group is chiefly affected.[3]

In our case this cystic tumor was not detected on x-ray examination of the chest nor was it suspected clinically. It is interesting to speculate as to what the eventual outcome of this cyst would have been had the patient survived.

SUMMARY

A case of benign mesothelial cyst of the epicardium is reported and discussed.

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INTRACARDIAC KNOTTING OF THE CATHETER IN HEART CATHETERIZATION

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STOCKHOLM, SWEDEN

SERIOUS complications of heart catheterization appear to be rare. The risk of intracardiac knotting of the catheter has hitherto aroused little comment in the literature. Certain writers[1,2] have pointed out the importance of avoiding looping and kinking of the catheter in its passage through the heart. A case was presented in which kinking of the distal end of the catheter caused it to be [illegible] and necessitated surgical intervention for its removal. But a search of the literature has revealed no reports of more complicated catheter knot formation. We wish therefore to describe our mode of procedure in three cases of intracardiac knotting of the catheter.

It is sometimes difficult to guide the catheter from the right atrium to the right ventricle. Difficulties may also arise in its passage from the right ventricle into the pulmonary artery. Protracted rotatory manipulation may be required before the catheter follows the desired direction. And in cases in which the [illegible] effective fluoroscopic control [illegible] during the manipulations. Constrictive pericarditis is such a condition. Here the pulmonary artery pressures are also of the greatest importance in assessing the patient's condition. During persistent attempts to [illegible] the catheter into the pulmonary artery, fluoroscopic visualization of the [illegible] should last for [illegible] seconds, which time may suffice to permit [illegible] looping.

A general anesthetic was given, and the knotted catheter was then easily withdrawn through the median cubital vein. Fluoroscopic visualization was very difficult in this patient. The appearance of the knot is shown in Fig. 1.

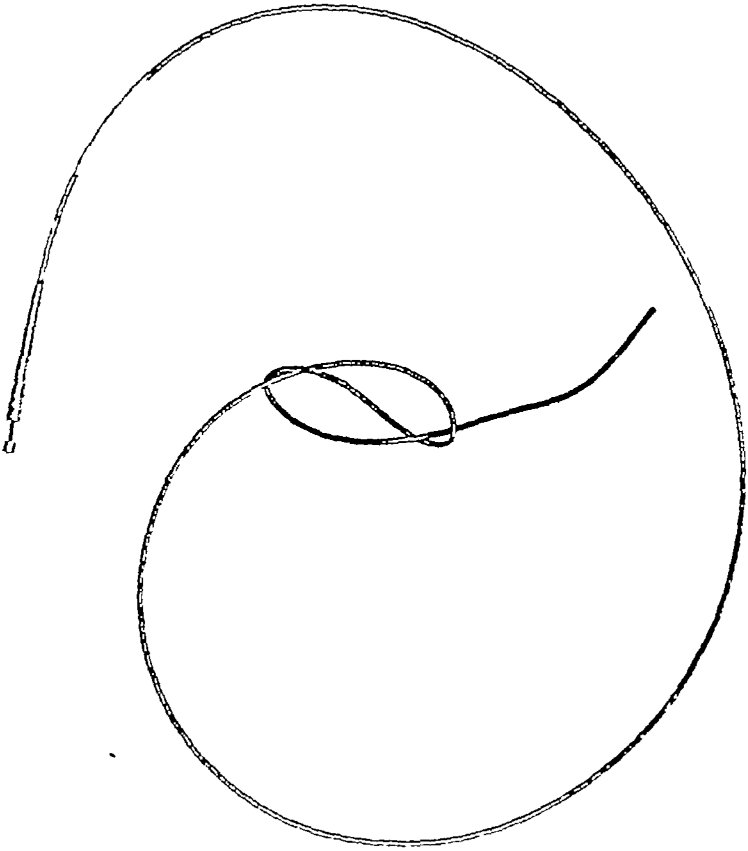


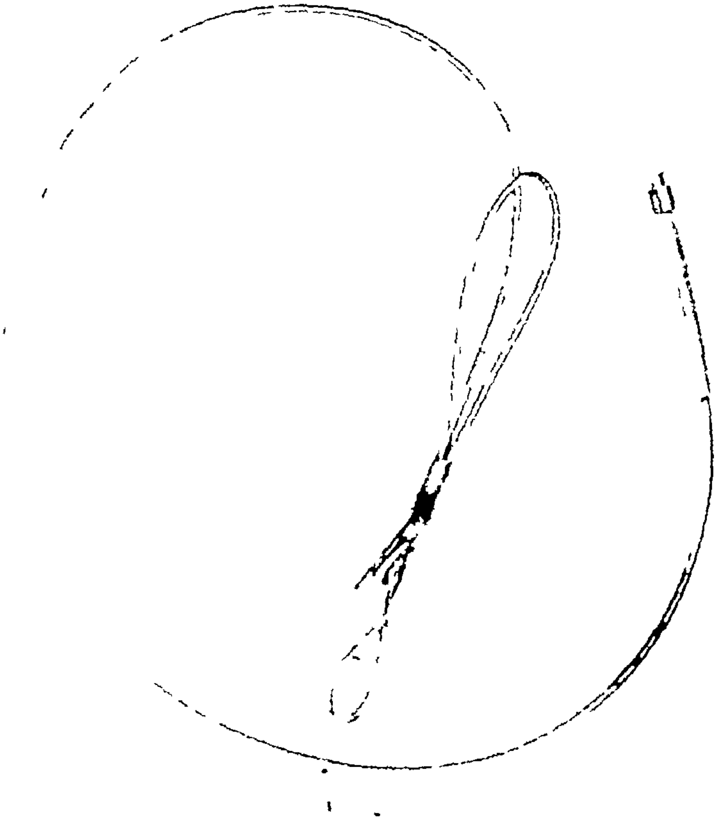
Fig. 1

In the third instance a No. 9 catheter formed a large loop in the right ventricle. When the operator tried to straighten the loop it rotated on its long axis so that two more loops were added to that already present. The result was a small coil of catheter in the right atrium. All attempts to disentangle the coil were without effect. It was therefore cautiously drawn up through the superior vena cava and out of the thorax until its passage was arrested at the level of the axilla on the left side. The patient was anesthetized and the catheter removed. But with it came the final portion of the basilic vein which had to be excised. The coil of catheter is shown in Fig. 2.

No cardiac arrhythmia was registered during the manipulations for catheter withdrawal in these cases. The patients suffered no aftereffects and none of the catheterized vessels became thrombosed.

DISCUSSION

Constant effective fluoroscopy is essential for preventing intravascular knotting of the cardiac catheter. Coiling and looping must be avoided. If these [illegible] an attempt should be made with all possible speed to straighten out the catheter. Should a knot form withdrawal of the catheter would appear to be facilitated by anesthetization of the patient. This is probably because anesthesia relaxes the spastic state of the venous walls and simultaneously eradicates the associated pain reaction. A favorable relaxation of the shoulder and upper arm musculature is also achieved. The report shows that it is possible to remove the catheter without anesthesia even when the knot is of fairly considerable dimensions.



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CRYPTOCOCCOSIS OF THE LUNG

REPORT OF TWO CASES WITH SUCCESSFUL TREATMENT BY LOBECTOMY

J. KARL POPPE, M.D., PORTLAND, OREGON

CRYPTOCOCCOSIS or torulosis is a fungus disease which may be found in any part of the body but has a special predilection for the brain and meninges, where it is ordinarily fatal within six months. About one fourth of the 127 patients reviewed by Ratcliff and Cook[1] showed pulmonary involvement either alone or as an initial stage of the disease before extension into the brain. Pulmonary disease appears to have a much better prognosis than cerebral disease, which represents the cause of death in most of the cases reported in the literature.

Considerable confusion of nomenclature is found in discussions of this fungus,[2] the most popular names for which are *Cryptococcus neoformans* and *Torula histolytica*. Other names are Saccharomyces sp., *Saccharomyces neoformans*, *Cryptococcus hominis*, *Torula neoformans*, *Cryptococcus histolyticus* and *Cryptococcus meningitidis*. The disease is known as cryptococcosis, torulosis, Busse-Buschke disease and European blastomycosis. It is not to be confused, however, with American blastomycosis, which is caused by *Blastomyces dermatitidis*. *Cryptococcus neoformans* is identified by Giemsa's stain and grows on Sabouraud's medium. It is a round organism with a thick-walled refractile capsule. It produces pseudohyphae and buds but does not produce mycelia. In contrast to yeasts, Torula ferments sugars little or not at all.

In early cases of pulmonary involvement with cryptococcosis the patients are usually relatively asymptomatic, with perhaps only a slight nonproductive cough, usually attributed to cigarettes. The diagnosis of torulosis in these patients is not suspected at that time, since only a localized area of pneumonitis is found on a routine chest film, which area is ordinarily suspected of being a tumor. It is only on pathologic examination of the resected surgical specimen that the correct diagnosis is made. While still in a curable stage the fungi are encapsulated and not available for a positive laboratory test preoperatively by studies of either sputum or of bronchoscopic aspiration.

REPORT OF CASES

CASE 1.—This 4[illegible]-year-old grocery owner (J. M. P.) was discovered to have a spot on his lung on a routine tuberculosis survey film on July 1, 1952, at the Seattle Health Department. A similar film taken in 1951, as required annually of all food handlers, had been reported as negative. Examination at Barnes Veterans Hospital in Vancouver, Washington, showed an apparently healthy afebrile man who weighed 17[illegible] pounds. He had had a chronic cough with one tablespoonful of yellow-white sputum daily for many years. There was a history of mild intermittent asthma since childhood and of cat fever while in the Navy in World War II. He had had acute exacerbations of his chronic bronchitis about four times yearly. His personal and family histories were negative for tuberculosis.

Reviewed in the Veterans Administration and published with the approval of the Chief Medical Director. Statements and conclusions published by the author are the result of his own study and do not necessarily reflect the opinion or policy of the Veterans Administration.

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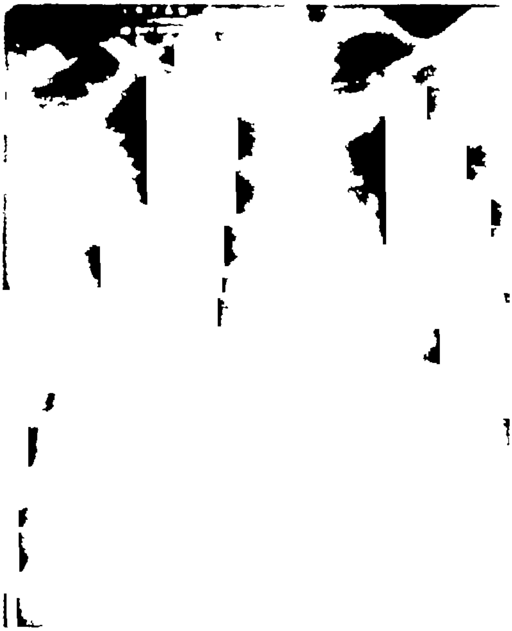

[illegible]

Additional chest films taken in August 1952, showed no change in the shadows seen on the film two months earlier. It still represented a 4 cm. fairly round mass seen in the fourth anterior intercostal space in the midaxillary line. Repeated sputum examinations were negative for tuberculosis on smear and culture. A bronchoscopic examination on Aug. 26, 1952 was essentially *negative,* as were the bronchoscopic aspirations examined for tumor cells.

An exploratory thoracotomy was performed on Sept. 2, 1952, under the assumption that the x-ray shadow might represent a malignancy. The fifth rib was resected, and inspection of the underlying lung showed a *large, hard, nodular mass in the periphery of the right upper lobe which had not extended beyond this local area.* Mediastinal lymph nodes removed from around the bronchi and trachea showed no tumor on *frozen section. The peripheral mass was well localized and rubbery rather than stony hard, so a lobectomy was elected rather than a pneumonectomy,* since considerable doubt existed regarding the presence of a true malignancy. Individual ligation technique was used on all of the *blood vessels and the right upper lobe bronchial stump.* A *modified thoracoplasty* was performed at the same operation with removal of the second, third and fourth ribs in addition to the fifth one previously removed. Two intercostal thoracotomy tubes were *inserted in the pleural space and connected to an empyema bottle with a water seal.* The tubes were completely removed six days postoperatively following an uneventful course with complete re-expansion of the remaining lung to fill the pleural space.

Pathologic examination of the surgical specimen showed a solid granulomatous lesion limited to the periphery of the right upper lobe containing large numbers of round organisms with a thick-walled refractile capsule identified by the pathologist* as *Cryptococcus neoformans.*

The diagnosis of cryptococcosis came as something of a surprise and incited another series of sputum examinations without the finding of any *evidence of fungi on smear or culture.* The usual course of 800,000 units of penicillin and 1 Gm. of streptomycin was given daily over a period of two weeks and the patient was discharged about three weeks postoperatively, having been completely *afebrile during the previous two weeks. Outpatient examinations failed to show any evidence of disability or recurrence eighteen months postoperatively.*

CASE 2.—This [illegible]-year-old salesman of metal products was discovered to have a *paramediastinal shadow on the right lung in the region of the right middle lobe on a* tuberculosis survey film in April 1953. He had lived in Portland, Oregon, during the previous four years after leaving Oakland, California. A diagnosis of pneumonia had *been made elsewhere after a negative sputum examination for tuberculosis* was obtained. Despite two months of intermittent treatment with Aureomycin, his temperature of around 100° F. daily persisted and the pain in his right chest gradually increased. During this *period of treatment the right lung shadow tripled in size associated with progressive* weakness, until he was unable to work by mid-July, when he came under my care.

A bronchoscopic examination on July 24 was completely negative as was the pathologic examination of the aspirated secretions *for tumor cells.* The possibility of a malignancy or fungus disease was considered and an *exploratory thoracotomy was performed* on Aug. 3, 1953. Examination at this time *showed a firm, rubbery consolidation involving the* anterior portion of the right upper lobe and the entire right *middle lobe and extending* across the fissure to include part of the *right lower lobe.* Large rubbery lymph nodes were present in the hilar area. *Frozen section of a biopsy showed only a chronic inflammatory process.* A total right pneumonectomy was *performed* including the hilar and mediastinal nodes.

Pathologic examination of the surgical specimen showed most of the lung structure in the granulomatous areas *to be obliterated by an inflammatory process* which was composed essentially *of isolated islands of tissue with doubly refractile bodies* within them some of which showed budding. A *diagnosis of torulosis was made on the basis of the* pathologic sections as well as the fresh smears with special stains.

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*Dr. Jacobson.

[illegible] postoperative [illegible] uneventful with the exception of a transient diarrhea. [illegible] of penicillin and 1 Gm. of streptomycin was given daily until [illegible] postoperative day. Undecylenic acid was started [illegible] orally [illegible] the diarrhea subsided [illegible] the tenth postoperative [illegible] 8 Gm. daily for two months. A [illegible] was [illegible] treatment [illegible] No recurrence of his disease was [illegible] examination six months postoperatively.

[illegible]

[illegible]

[illegible] unable to sur[illegible] [illegible] lung, brain and [illegible] response of this disease to any drug or antibiotic with the exception of the work of Reilly and Artman,[7] who concluded that sulfadiazine and streptomycin would prolong the life of white rats but would not cure them. No cures have been attributed to iodides, which have long been recommended for fungus diseases of all types. Taber[8] stated that until an antibiotic more specific for Cryptococcus is found iodides might even be contraindicated. Johnson and associates claimed that of four theosemicarbazones tested in vitro bromothiazone proved the best. Klingman and Weidman[10] tested fatty acids, napthoquinones, antibiotics, and carbamide derivatives, concluding that actidione is the best in vitro, but that blood inactivates all of them and that theocarbonates are best in vivo. They recommended hyperpyrexia, holding the patient at 40° C. for six days, but no reports are available of any patient tolerating that temperature for the full period of treatment. Miller and associates[11] claimed that stilbamidine does not effect the clinical course of cryptococcosis.

Most recent clinical reports favor the use of actidione as being the best antibiotic available, even though it is not very effective. Actidione is an antifungal antibiotic prepared from *Streptomyces griseus* and represents a forerunner of streptomycin. Wilson and Duryea[12] reported a patient who was cured of *Cryptococcus meningitidis* for twenty months following a six-month course of actidione with 40 mg. each day intravenously. Carton[13] reported four patients treated with actidione, of whom two were dead and two alive, one of whom was considered cured. He also reviewed the literature and found most of the ten patients to have died who were reported as having been treated with actidione.

Hopkins and Murphy[14] reported a case of systemic spread of blastomycosis following resection arrested with undecylenic acid. Although American blastomycosis and cryptococcosis or European blastomycosis are not the same disease, long chain fatty acids have been reported as beneficial against several varieties of pathogenic fungi and may be useful in treating cryptococcosis.

Dormer and associates[3] in 1945 reported a lobectomy for cryptococcosis followed later by a fatal spread to the central nervous system. Froio and Bailey[15] reported a five and one-half year asymptomatic postoperative observation period following a lobectomy for localized pulmonary cryptococcosis in a 19-year-old man. Palmrose and Losh[4] reported a segmental lobectomy for torulosis followed by death from cerebral involvement four years later. I was involved with several subsequent operations on this patient and I wonder whether a whole lobectomy rather than a segmental one would not have provided a wider margin of normal tissue and longer period of survival in this case.

McConchie[5] of Australia reported pulmonary resections in three patients with pulmonary cryptococcosis since 1949, but both the case histories and periods of postoperative observation seemed quite brief. One patient still had untreated cerebral torulosis and another a contralateral pulmonary lesion when reported. No medical treatment was mentioned in any of the patients.

Over 200 cases of cryptococcosis have been reported, but of these surgical resection of involved lung tissue has been performed in only eight patients, including the three reported from Australia. The two patients reported here were still living and well when last examined.

CONCLUSIONS

1. Cryptococcosis is a relatively rare disease with only slightly over 200 cases being reported in this country.

2. Involvement of the central nervous system represents the most frequent location and cause of death.

3. Pulmonary involvement occurs before or associated with cerebral involvement in about one fourth of the patients.

4. Pulmonary resection represents the most logical treatment of this disease confined to a local area. Eight such resections have been reported.

5. Medical treatment of cryptococcosis has been very unsatisfactory, although sulfonamides and actidione have produced the most favorable reported results.

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18. [illegible] J. A. M. A. [illegible]

PULMONARY TELANGIECTASIA: REPORT OF CASE PROVED BY PULMONARY BIOPSY

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IN THE past decade congenital arteriovenous communications or shunts in pulmonary circulation have been recognized more frequently than formerly as a cause of cyanosis. A number of terms have been applied to such circulatory shunts, including "pulmonary arteriovenous aneurysm," "arteriovenous fistula," and "cavernous hemangioma of the lung." In cases where the lesions are multiple the descriptive term "congenital pulmonary telangiectasia" is probably preferable.

Undoubtedly increasing interest in these lesions has paralleled the recent advances in diagnosis and surgical treatment of cyanotic heart disease. In 1897 Churton[3] first identified a pulmonary arteriovenous fistula at autopsy and twenty-one years later Wilkens[14] reported a similar post-mortem observation. The first known ante-mortem diagnosis of arteriovenous fistula of the lung was made in 1939 by Smith and Horton,[11] who accurately correlated the symptoms and diagnosis. Sloan and Cooley[10] recently reviewed eighty-five reported cases and added nine more from The Johns Hopkins Hospital. Several later reports bring the total published cases to more than 100.[6, 11, 12, 15]

The findings in a typical case of pulmonary arteriovenous fistula include cyanosis of varying degree, polycythemia, clubbing of the nails, and the presence of a normal heart. Demonstration of a continuous humming murmur on the surface of the chest may localize the point where a large fistula is in proximity to the rib cage. Radiographic examination usually reveals a tumefaction of homogeneous density of variable size and shape and in continuity with hilar vascular shadows. Laminagraphic studies may be useful in revealing the connection between the lesion and the pulmonary vascular tree, but angiocardiography is the most helpful technique available to define the true nature of such lesions.

Recently we observed a moderately cyanotic patient in whom the diagnosis of pulmonary arteriovenous fistula was suspected from the history and clinical findings, but the diagnosis was not established by radiographic methods including angiocardiography. The diagnosis in the case was verified by exploratory thoracotomy and biopsy of the lung. To our knowledge this is the first case of suspected multiple pulmonary telangiectasia in which the patient was actually submitted to thoracotomy for the purpose of establishing the diagnosis by pulmonary biopsy.

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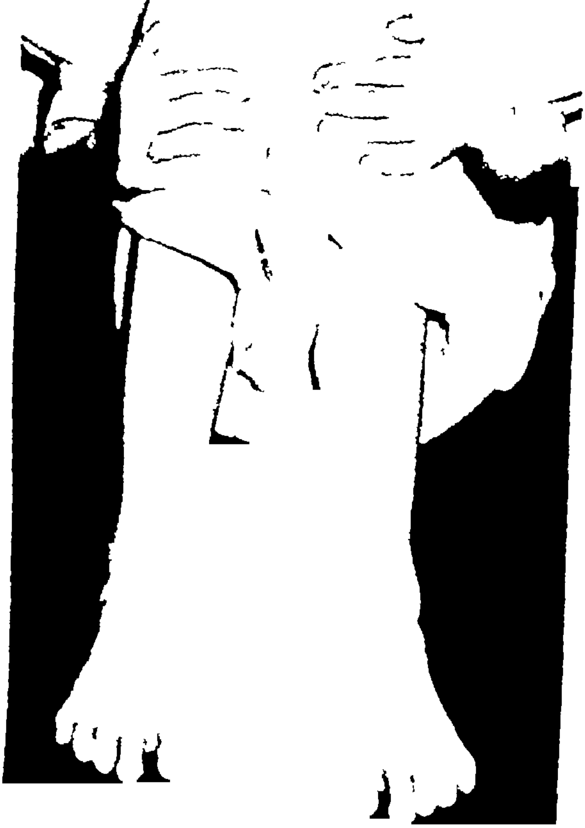

[illegible] cupping of the finger and toe nails which [illegible]

REPORT OF A CASE

M. R. V., a 7-year-old white girl, was admitted to the Methodist Hospital on Sept. 25, 1953, because of mild dyspnea which had gradually increased during the preceding eighteen months. Except for occasional mild infections of the upper respiratory tract she had been in good health. About seven months prior to admission her aunt, a registered nurse, noticed clubbing of the patient's nails (Fig. 1) and mild, but increasing, cyanosis which tended to appear after strenuous exertion.

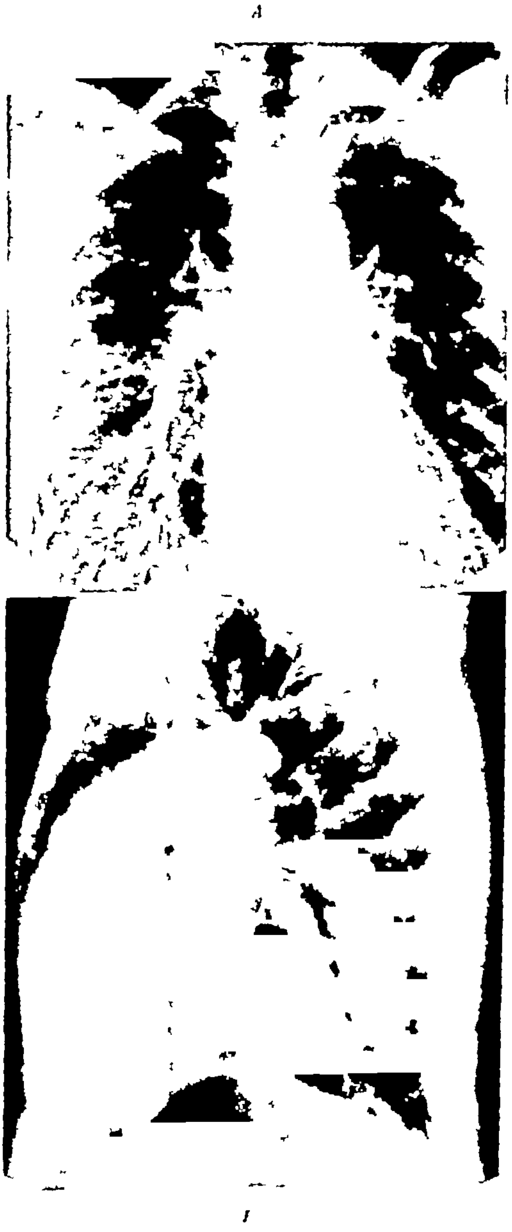

Fig. 3.—Angiocardiogram in the anteroposterior (A) and left lateral (L) projection showing normal circulation of contrast medium through the pulmonary arteries. Vascular markings in the lung bases appear more prominent than in the upper lobes and there is irregular beaded appearance in the arteries of small caliber.

[illegible] weighed 7 pounds [illegible] ounces at birth. At [illegible] days of age [illegible] small hemangioma on the back, and when she was [illegible] hemangioma was excised from the [illegible] of the trunk and extremities had persisted since [illegible]. The [illegible] of epistaxis, hemoptysis or other hemor[illegible] abnormal development until appearance of the [illegible] clubbing of the [illegible]. Numerous examinations by a referring [illegible] careful [illegible] failed to reveal any cause for [illegible].

The [illegible] maternal grandmother and a great aunt as well as [illegible].

[illegible]

with 83 per cent segmenters, 5 per cent band forms, 5 per cent lymphocytes, 2 per cent monocytes, and 1 per cent eosinophils. A sample of femoral arterial blood was found to have an oxygen saturation of 81.4 per cent. Urinalysis yielded a specific gravity of 1.020, no protein or sugar, and 10 to 15 leukocytes per microscopic high power field.

A

Fig. —Photomicrographs of section of pulmonary biopsy. At low magnification (A) there are visible at least three subpleural arteriovenous aneurysms measuring [illegible] to 4 mm in diameter, and the deeper pulmonary parenchyma appears normal. At higher magnification (B) foci of angiomatous proliferation of mature type are revealed.

Fluoroscopy of the chest revealed the heart to be of normal size and configuration with normal pulsation. No unusual pulsations were observed in the hilar region, but pulmonary markings appeared accentuated, particularly in the bases. Roentgenograms of the chest exhibited accentuated peripheral pulmonary markings but failed to demonstrate any isolated pulmonary lesion (Fig. 2). Angiocardiogram demonstrated normal circulation of the contrast medium through the heart and great vessels without evidence of abnormality. Vascular markings were more prominent in the bases of the lungs than in the upper regions, but no area of pooling of the contrast medium was evident. Most of [illegible] beaded appearance extending out into the periph[illegible] and [illegible] the arteriolar divisions (Fig. [illegible]).

T[illegible] tachycardia (1[illegible] beats per minute) and right [illegible] with normal position of the heart and no evidence of [illegible] hypertrophy.

On Sept. [illegible] 1953 under ether [illegible] an exploratory thoracotomy was performed for [illegible] through a short left posterolateral intercostal incision. The [illegible] surface appeared pink and glistening. As the lung was deflated multiple [illegible] plate[illegible] the surface of the lower lobe as well as a lesser number [illegible] in the upper lobe [illegible] (Fig. 4). A filamentous capillary net[illegible] bright red [illegible] vessels observed on the visceral and parietal [illegible] blood-filled telangiectatic areas were discernible in the [illegible]. The [illegible] peripheral distribution of the lesions and the probability that

DISCUSSION

The observations in this case indicate that the multiple minute pulmonary arteriovenous fistulas were a manifestation of the disorder described by Osler[12] Weber[19] and Rendu[13] termed "hereditary hemorrhagic telangiectasia." Criteria for the diagnosis of Osler-Weber-Rendu disease include a definite history of heredity, visible telangiectasis with a pathologic distribution and a tendency toward bleeding from these lesions. The fact that about 40 per cent of patients with pulmonary arteriovenous fistulas have telangiectasis in other parts of the body strongly suggests that the pulmonary lesions represent merely a localized manifestation of a generalized capillary abnormality. In many reported cases, attention has been called to the fact that the pulmonary lesion appeared to be a manifestation of hereditary hemorrhagic telangiectasia.[5, 10, 14] Multiple minute pulmonary arterial fistulas may shunt enough blood, an estimated 30 per cent of the total circulation,[7, 10] away from the pulmonary alveoli and capillary network to produce cyanosis even though no lesion may be visible radiographically. Brink[1] reported a case of a patient 19 years of age with cutaneous and abdominal visceral hemangiomas proved by laparotomy in whom there was a familial history of telangiectasia. Although that patient was cyanotic, had clubbed fingers and had an arterial oxygen saturation of only 70 per cent, the pulmonary lesions were not demonstrable radiographically, including angiocardiography. Exploratory thoracotomy was not carried out. In other reported cases of patients with generalized telangiectasia, cyanosis has been attributed to peripheral rather than central vascular factors.[4, 9] In these instances the coexistence of pulmonary arteriovenous fistula was not strongly considered or else was felt to be of academic interest only, and thoracotomy was not recommended. In the case herein reported there were multiple telangiectases over the surface of the body varying in size from pin point to 2 cm. in diameter, and plethora was probably attributable to cutaneous capillary abnormalities as well as to cyanosis and polycythemia.

A definite familial history of hemangiomas as existed in our case has been found in about 15 per cent of reported cases of pulmonary arteriovenous fistulas, and in three instances the pulmonary lesions have been discovered in siblings.[6, 10]

Absence of bleeding manifestations characteristic of Osler-Weber-Rendu disease in our patient does not exclude the case as an example of hereditary telangiectasia since hemorrhagic phenomena may not appear until the third or fourth decade of life or even later. It is entirely possible, therefore, that our patient may subsequently exhibit a bleeding tendency. Typical manifestations include hemoptysis, hematemesis, melena, hematuria and cerebrovascular accidents. At autopsy telangiectases have been found in the skin, nose, mouth, pharynx, larynx, trachea, stomach and duodenum. The tendency toward chronic bleeding in these cases may lead to severe secondary anemia.

In the usual case of pulmonary arteriovenous aneurysm the diagnosis may be strongly suggested by the standard roentgenographic techniques and further confirmed by angiocardiography. Whereas the diagnosis of pulmonary arteriovenous fistula can usually be readily established by these techniques, in the exceptional case such as that reported here, multiple minute lesions may not be sufficiently well visualized by contrast medium in the pulmonary artery to establish the diagnosis unequivocally. In such instances, limited thoracotomy with exploration of the lung and excision of a specimen for biopsy is justifiable. Because the diagnosis in our case was more easily and thoroughly established by thoracotomy, cardiac catheterization was unnecessary, although it would have provided interesting data for following the physiologic changes, particularly in cardiac output, as the patient grows older and cyanosis increases.

The pathologic findings on biopsy in this case were particularly striking. Microscopically, each lesion exhibited the characteristic appearance of pulmonary arteriovenous fistula as described by Yater and his associates:[7] namely, the presence of a distended thin-walled afferent artery, distended efferent veins, and an intervening vascular sac consisting of distended vessels. Although these pulmonary lesions have been called pulmonary angiomas or cavernous hemangiomas of the lung, in most instances the histologic findings have been similar to those associated with acquired arteriovenous fistula in the systemic circulation. Biopsy in this patient offered the additional advantage of permitting histologic study of a generalized angiomatous change occurring in the pulmonary capillary system and possibly elucidating the pathogenesis of pulmonary arteriovenous fistulas. According to Yater and his associates, the vascular components of the lesion apparently gradually become more dilated, and the degenerative changes which may occur contribute to formation of even more intercommunications between pulmonary arterioles and venules with resultant occasional rupture and hemorrhage into the alveoli or pleural cavity. Thus this case would appear to provide a unique opportunity to observe the progress of the pulmonary telangiectases clinically and [illegible]. It is planned to review the case several years hence and, [illegible] to take lung tissue if possible in an attempt to establish [illegible] of the pathologic process revealed by the initial

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ONE STAGE THORACOPLASTY USING THE TRAPP ADHESIVE HEMICAST

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IN ALASKA hospital beds for the treatment of tuberculosis are extremely inadequate to meet existing needs. The vast majority of patients admitted for tuberculosis have been on the waiting list for two years or longer. Only two hospitals in Alaska offer major surgical treatment for tuberculosis. Under such conditions any collapse procedure which can speed up the discharge of arrested cases without serious increase in mortality and morbidity deserves adequate trial [illegible].

In November 1951 Trapp presented his original work on a thoracoplasty [illegible] with stabilization of the chest wall against paradoxical respiratory movements by use of an adhesive plaster cast. He suggested that the procedure might be used routinely, eliminating one or more stages of the Alexander technique. Since that time ninety nine consecutive graded thoracoplasties for collapse of tuberculous lung tissue have been carried out on Eskimo, Indian and Aleut patients at the Mt. Edgecumbe Hospital as a single stage [illegible] operated this. In forty one of these cases the Trapp adhesive hemicast was used to eliminate motion of the flail chest wall with [illegible] results.

TABLE I THORACOPLASTIES STABILIZED BY TRAPP HEMICAST

CASE NO.	AGE	SEX	DATE OF SURGERY	SIDE	NUMBER OF RIBS	UNITS BLOOD	SHOCK THERAPY (HR.)	FREQUENCY OF HYPOS (HR.)	COMMENTS
1 JA	21	M	11/29/51	R	6	[illegible]	7	3	Complained of heat from setting plaster atelectasis relieved by tracheal aspiration
2 RP	19	M	12/13/51	L	6	3	2	4 8	
3 EM	[illegible]	M	12/13/51	L	8	4	5½	10	
4 ME	21	F	12/18/51	R	5	2	7	3	
5 LC	39	F	12/20/51	L	8	3	4½	3 4	
6 CT	26	F	1/ 3/52	L	6	3	9	4	Partial scapulectomy
7 MT	28	F	1/24/52	R	10	3	2½	4 7	
8 AM	28	F	1/24/52	R	6	3	6	6	
9 SA	23	M	1/31/52	L	8	2	3¼	3½ 7	
10 LE	31	M	2/ 7/52	L	6	2	2	4	
11 GA	[illegible]	M	2/ 7/52	R	6	2	14	3 7	Pleural tear sutured Thoracenteses 4th and 7th days Hemiplegia 32nd day and expired 36th day Hemorrhage into right cerebral ventricle
12 MY	49	F	2/14/52	L	9	2	9	[illegible] 4	One water seal drain left in subscapular space 5 days because of large pleural tear
13 MC	20	F	2/14/52	L	7	2	5	4 9	
14 BB	13	M	2/26/52	L	6	1½	6¾	[illegible] 6	Five rib thoracoplasty on right side 4/15/52
15 JS	27	M	2/28/52	R	8	3	5¼	5½ 7½	Digitalized on 4th postoperative day for persisting tachycardia
16 TA	30	M	2/28/52	R	6	2	[illegible]½	[illegible]	
17 RT	55	F	3/ 6/52	R	6	2	7¾	5 14	
18 JP	19	M	3/27/52	R	5	1	3	[illegible] 6½	Right pneumonectomy 2/18/5[illegible]
19 WW	21	M	4/ 9/52	L	7	2	2½	1 9	
20 JO	26	M	4/10/52	R	8	2	5	1 8	Right thoracenteses 4/14 and 4/15 Cast removed 4/15 and reapplied
21 AY	21	M	4/14/52	R	6	2	5	4	Pleural tear sutured No thoracentesis
22 EB	17	M	4/16/52	L	6	2	2½	5	Right 5 rib thoracoplasty on 6/25/52
23 BG	39	F	6/10/52	R	7	2	4¼	5 6½	Sudden shock 27 hr postop Thought to have pulmonary embolus Coughed up plug of inspissated mucus on 6/18/52
24 FS	27	F	6/19/52	L	7	2	12	4 9	Pregnancy in 2nd trimester Normal delivery 11/11/52
25 DF	44	M	6/26/52	R	6	2	6	5	
26 GB	17	F	7/ 2/52	R	6	2	2	4 12	Partial scapulectomy
27 LB	20	M	7/ 8/52	L	6	2	3¾	[illegible]	Partial scapulectomy
28 JC	39	M	8/12/52	L	8	2	4	[illegible]	Thoracentesis 8/18

TABLE I—Continued

[illegible]	[illegible]	SEX	[illegible]	SIDE	[illegible]	[illegible]	[illegible]	[illegible]	COMMENTS
[illegible]	[illegible]	F	[illegible]	L	7	–	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	L	5	2	–	[illegible]	Left 4 rib thoracoplasty 10/26/52
[illegible]	[illegible]	M	[illegible]	L	8	–	[illegible]	[illegible]	
[illegible]	[illegible]	M	[illegible]	L	5	2	21	[illegible]	
[illegible]	[illegible]	M	[illegible]	R	6	–	[illegible]	[illegible]	
[illegible]	[illegible]	M	[illegible]	R	5	2	–	[illegible]	Pleural tear sutured. Thoracenteses on 10/4 and 10/[illegible]. Left 4 rib thoracoplasty on 1/8/53
[illegible]	[illegible]	M	[illegible]	R	6	2	11	[illegible]	
[illegible]	[illegible]	F	[illegible]	L	6	2	5	[illegible]	Partial scapulectomy. Attempted thoracentesis on 1/[illegible] yielded no fluid
[illegible]	[illegible]	M	[illegible]	L	7	–	[illegible]	[illegible]	Partial scapulectomy
[illegible]	[illegible]	M	[illegible]	L	6	–	[illegible]	[illegible]	Thoracentesis 1/26 with cast removed
[illegible]	[illegible]	F	[illegible]	L	7	[illegible]	[illegible]	[illegible]	Partial scapulectomy. Thoracenteses 2/[illegible] and 2/4 with cast removed on 2/[illegible]
[illegible]	[illegible]	F	[illegible]	L	6	–	3	[illegible]	Partial scapulectomy. Cast removed on 2/[illegible] because of pressure at edge
[illegible]	[illegible]	M	–	L	6	–	2	[illegible]	

[illegible] bleeding from the rib stumps by small oxycellulose packs. The scapula was [illegible] down and tested for impingement on the remaining ribs and where [illegible] partial scapulectomy was carried out. A suction catheter was left [illegible] space during most of the closure to remove trapped air

[illegible]

the entire chest and cast was wrapped with three inch elastic bandages. The patient was then returned to his room and placed on his operated side with 10 inch elevation of the foot of the bed until the blood pressure had remained stable with the systolic pressure above 100 mm. Hg for at least two hours. Intranasal oxygen and intravenous blood and fluids were also given during this time. The cast was left in place for five to twelve days.

DISCUSSION

Prior to the development of the modern thoracoplasty, paradoxical respiratory movement in the flail chest wall had caused serious postoperative shock with a high mortality rate. This hazard was effectively controlled when the procedure was broken down into several stages of two or three ribs each. The satisfactory completion of ninety-nine consecutive thoracoplasties in single stages was made possible only by the availability of an effective method of controlling paradoxical motion.

The forty-one cases which required the Trapp adhesive hemicast to stabilize the chest wall are evaluated in Table I. The ages of this group ranged from 13 to 62 years with an average age of 30.5 years. There were sixteen women and twenty-five men patients. Twenty were operated on the left side and twenty-one on the right. The number of rib segments taken at the single procedure varied from five to ten, with an average of six and one half. Postoperative shock was unusually severe in four cases (1, 15, 23, and 35). Two of these patients had postoperative atelectasis, one relieved by tracheal aspiration and the other misdiagnosed as pulmonary infarction until she coughed up a plug of inspissated mucus on the eighth postoperative day. One patient was digitalized on the fourth postoperative day because of a persisting rapid, feeble pulse. There were no preoperative conditions in these cases which might have suggested the preference of a staged procedure. All cases survived the immediate postoperative period and only one death has occurred (No. 11) and this was due to a cerebrovascular accident on the thirty-second postoperative day with death on the thirty-sixth day. This patient's condition was considered satisfactory up to the onset of hemiplegia and the death is believed not to be associated with the technique of thoracoplasty. The average time of elevation of the foot of the patient's bed after surgery was six and one quarter hours.

Blood replacement varied from 1 to 4 pints with an average of 2.3 pints per patient.

An attempt was made to estimate postoperative pain according to the period of pain relief between hypodermics of Pantopon or Demerol during the first forty-eight hours postoperatively. This appears to be comparable to that in our previous first stage thoracoplasties with the removal of three ribs. Many patients were found to be remarkably free of severe postoperative pain and these cases were for the most part among the men with little subcutaneous fat. Women with large breasts and with a thick adipose layer under the skin were apt to complain of pressure at the edge of the cast. In one case the complaint was

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wall was controlled satisfactorily by the Trapp adhesive hemicast. Complications were treated without serious difficulty. Slight increase in morbidity was well justified by the increased rate of definitive treatment and the reduced mental trauma of the individual patient.

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